MEDICAL THERMOGRAPHY IN PERSPECTIVE

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Abstract: Infrared scanning systems (Thermographs) have added a new dimension to medical diagnosis. The principles of thermography are discussed with special emphasis on the development of instrumentation suitable for clinical and research applications in medicine and biology. Requirements for suitable environmental control and instrument flexibility and means for achieving reliable, reproducible results are described. A summary of the wide range of current medical uses and potential new applications is presented. Special emphasis is placed on breast cancer detection and early diagnosis of extracranial cerebrovascular disease.

During the last fifteen years, thermography has become increasingly attractive to physicians and scientists as an aid to clinical diagnosis and research in medicine. Since 1870 when the modern clinical thermometer was finally perfected, numerous attempts have been made to increase the diagnostic meaning of thermal measurements by a host of techniques. A truly non-destructive clinical test, which in no way altered or compromised the patient to be studied yet provided accurate thermal measurements, seemed highly desirable. Accordingly, various instruments, beginning with modified thermometers, progressing through thermocouples and thermistors, and finally non-contact radiometers, were developed, which have enabled scientists to make judgments about clinical and experimental disease states.

Thermography is diagnostically meaningful because: all objects above absolute zero emit infrared radiation; human skin is an excellent emitter in the infrared part of the electromagnetic spectrum; emitted radiant energy may be collected optically, transduced into electrical signals, amplified, and then processed and displayed; photographic radiance in the final visible images of thermograms is a function of the thermal variations that exist upon the skin at the time that measurements are made; pigmentations do not alter the skin's emissivity; the thermal patterns that occur on the skin are usually caused by (a) vascular patterns, (b) localized conditions of the skin, such as necrosis, erythema, irritation, hyperemia, infection, and (c) heat brought to the surface from organs of the body or from discrete pathological entities, such as neoplasms, traumatic injuries, or infections.

Since the advent of medical thermography, infrared scanners have been developed which are aimed at meeting the needs of physicians. The three most critical parameters of instrumentation are 1) speed or frame time, 2) thermal sensitivity, and 3) optical resolution. Broadly speaking, these parameters depend upon the scanning mechanism, the detector, and the visual or photographic display. It is usually necessary to trade off thermal sensitivity and optical resolution against frame time or speed. When theoretical thermal sensitivity and optical resolution are achieved at frame times greater than 24 per second, truly real-time thermography will exist, since there will be flicker-free presentation of highly resolved thermal information. For the time being, however, each user can usually select that combination of factors most appropriate to his work.

Generally, clinical diagnosis has been based upon the asymmetric distribution of temperature where bilateral symmetry is to be expected. In the diagnosis of breast cancer, for example, the finding of an unusual increase in temperature over an area on one breast that is not present on the contralateral side is cause for suspicion. While many users have relied on the qualitative examination of the thermogram to assess side to side differences in temperature, others have been concerned with quantitative thermal measurements. Truly accurate temperature measurements by non-contact radiometers currently available require the user to put a "blackbody" reference in the field of view. In this way, it is possible for the final grey tone of the film to be related to an absolute temperature value and for any grey tone on the clinical target to be assigned to a specific absolute temperature. This is usually accomplished by means of a densitometer and the varying transmission of light through the black-to-grey-to-white spectrum on the final thermogram. Our work has employed the thermal grey scale for this purpose. It consists of ten blackbody sources varying in temperature by 1°C. The temperatures were chosen to surround those found in clinical practice. A photocomparator (densitometer) is then employed to construct the curve and to determine the temperatures of interest on the patient examined.

The broadest use of thermography in the diagnosis of disease can be achieved when an appropriate clinical installation is available. An "ideal" situation would probably require a room whose outside dimensions were 16' x 16'. Since medically meaningful thermograms require that the patient reach equilibrium with the ambient temperature, cubicles are attached, which enable examinations to proceed while other patients come to equilibrium in a suitably private setting. For most purposes, the ambient temperature should be controlled to 72°F ±2°F. There should be no significant drafts. The relative humidity should be held to 60% or less so as to preclude perspriation and evaporative cooling of the subject. If the installation faces an outside wall exposed to the sun's heating, the windows on that wall should be draped or shaded in order to minimize the effects of infrared radiation from the outer to the inner walls.

Thermography has, to date, primarily been used for the detection of breast cancer.

Lawson's observation in 1956 that breast cancer was associated with increased temperature on the skin overlying the tumor served as the impetus for future studies designed to confirm and extend his research.

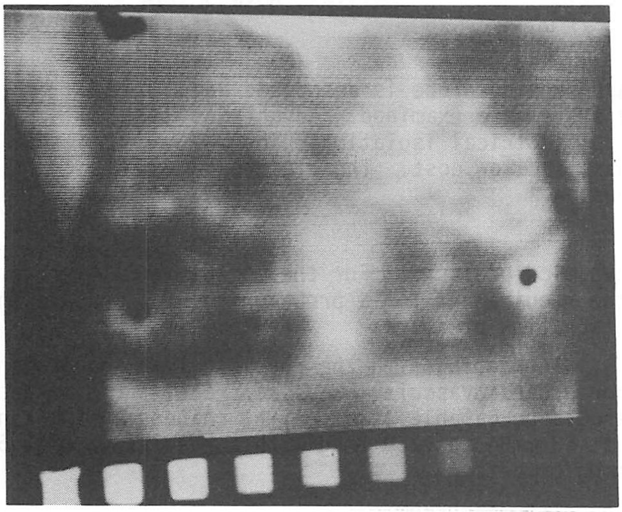

Figure 1. Cancer of the breast. Note increased temperature (white area).

Lilienfeld et al,[1] recently reported a collaborative study of 3,518 patients in several medical centers in order to determine the sensitivity and specificity of thermography as compared to mammography and physical examinations. The following results were obtained: Mammography: sensitivity, .703; specificity, .807; Thermography (read by same investigator for all cases with clinical data): sensitivity, .795; specificity, .773. As the authors point out, "It is important to note that the results of this study may be biased in favor of the mammogram and against the thermogram. Of those breasts which were positive on the physical examination, 64.4% had surgery or biopsy as did 64.9% of those positive on the mammogram. However, only 44.9% of those positive on the thermogram reading with clinical data had biopsy or surgery. It is apparent that the decision for biopsy or surgery was based primarily on physical examination and mammogram results; it is possible that thermography would show a higher sensitivity if a higher proportion of those positive on this test had a biopsy or were operated upon." There have been an increasing number of reports of individuals whose only positive parameter was a strongly positive thermogram and whose biopsy proved the presence of malignant disease. Some of these cases were biopsed on the basis of the thermogram alone. Others were biopsed when a mammogram, originally negative, became positive some time after a positive thermogram.

In 1965, Dr. Ernest Wood[2] reported his experience with thermographic detection of carotid disease. After establishing normal values of facial temperature through the examination of approximately 1,000 healthy subjects of varying ages, he proceeded to examine 132 patients with a variety of clinical conditions. Of 53 patients with unilateral carotid artery disease, Dr. Wood found abnormal thermograms in 47. In 11 patients with bilateral carotid artery disease, abnormal thermograms were detected in 9. In 68 patients whose disease was intracerebral, either vascular or neoplastic, only 7 had abnormal thermograms. Moreover, in virtually all of these, "false positives" there was reason to believe that there was a reversal of flow in the ophthalmic artery and a resultant "steal" phenomenon. As Dr. Wood points out, "The peculiar anatomy of the internal carotid artery (specifically, the surface display of two of its terminal branches on the forehead--the frontal and supra-orbital arteries) is the foundation for thermographic detection of vasal insufficiencies. The superficial terminal branches of the internal carotid artery are fed through its first major branch, the ophthalmic artery: this provides the blood supply not only to structures within the orbit but to the anterior ocular surface and the integument of the central forehead. In internal carotid artery stenosis or occlusion, blood flow through the ophthalmic arterial branches ordinarily is reduced, resulting in greater susceptibility of the skin to cooling and the production of a measurable temperature in a cool environment."

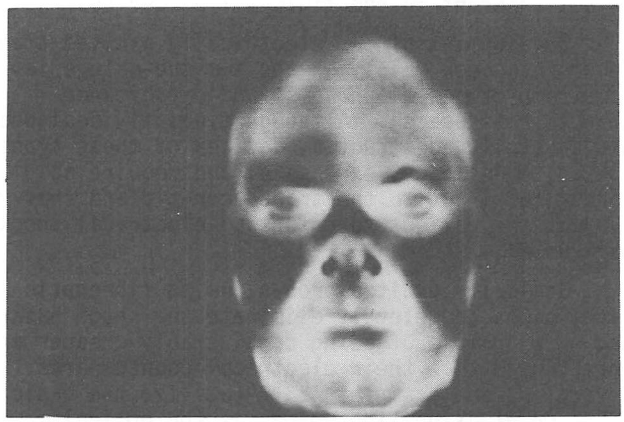

Figure II. Right internal carotid artery occlusion. Note cool area above right eye (black area).

It is not possible to describe and explain all of the clinical conditions in which thermography is useful in this brief report. However, the following list of reported areas of clinical application is an indication of its general usefulness: 1) The evaluation of peripheral vascular disease; 2) Placenta localization; 3) The evaluation of the degree of burn injury; 4) The differentiation of various pathological conditions of the eye; 5) Metastatic surveys; 6) Wound healing studies; 7) Transplantation rejection studies; 8) Soft tissue trauma; 9) Peripheral nerve injury and regeneration; and 10) Rheumatic disease, including the arthritides and low back syndromes.

Ref: 1. A.M. Lilienfeld, Cancer, 24, 1206 (1969)
2. E.H. Wood, Radiology, 85, 270 (1965)