THERMOGRAPHIC ASSESSMENT OF BURNS AND FROSTBITE*

RAY N. LAWSON, M.D.,
G. D. WLODEK, M.D. and
D. R. WEBSTER, M.D., *Montreal*

THERE IS A NEW ROLE for physicians today in the application of advancing technology to clinical medicine. For instance, the mapping of skin temperatures by the use of infrared scanning techniques has recently become possible. This direct observation of radiated heat patterns constitutes a completely new dimension in biological measurement. On the assumption that earlier and more accurate evaluation of burn and frostbite injuries would facilitate treatment, tests on experimental animals were made to ascertain whether or not infrared recording might contribute something useful in this field.

The recent dramatic advances in infrared technology arise chiefly from the American missile development program. It is important to recognize that modern infrared detection and image display systems bear little relationship to what in the past has been known as infrared photography. Even today, to the average doctor, the term "infrared" connotes something to do with photographing surface veins, taking pictures through haze, or spotting enemy soldiers at night through a snooperscope. In a sense, the term infrared photography is a misnomer. It is a relative term. Infrared emulsions used for medical photography are only sensitive up to the very near edge (about 0.9 μ) of the infrared spectrum. Infrared photographs contain an ingredient of responses to visual wave lengths. They bear no direct relationship to the temperature of the object, and any heat recorded on them is the result of *reflected* infrared radiation, in contrast to directly radiated energy (Fig. 1).

It is not necessary to be a physicist to understand the basic principles employed by the infrared scanner used in our experiments. The term "heat" is a relative one and refers to the energy of disorganized molecular motion. With the constant equalization of environmental conditions, this energy is steadily being distributed or "transferred" by conduction, convection or radiation. Modern infrared devices† that have the greatest practical application deal with radiated heat as opposed, for instance, to Fahrenheit's conduction mercury thermometer that has been in use since 1714. Electromagnetic waves (Fig. 2), whether they be light waves, x-rays, radio waves or infrared waves, all travel at approximately the same speed; that is, 186,000 miles per second. Thus, at a distance, the burn injuries from an atomic blast are received well in advance of the violence of the shock wave. The

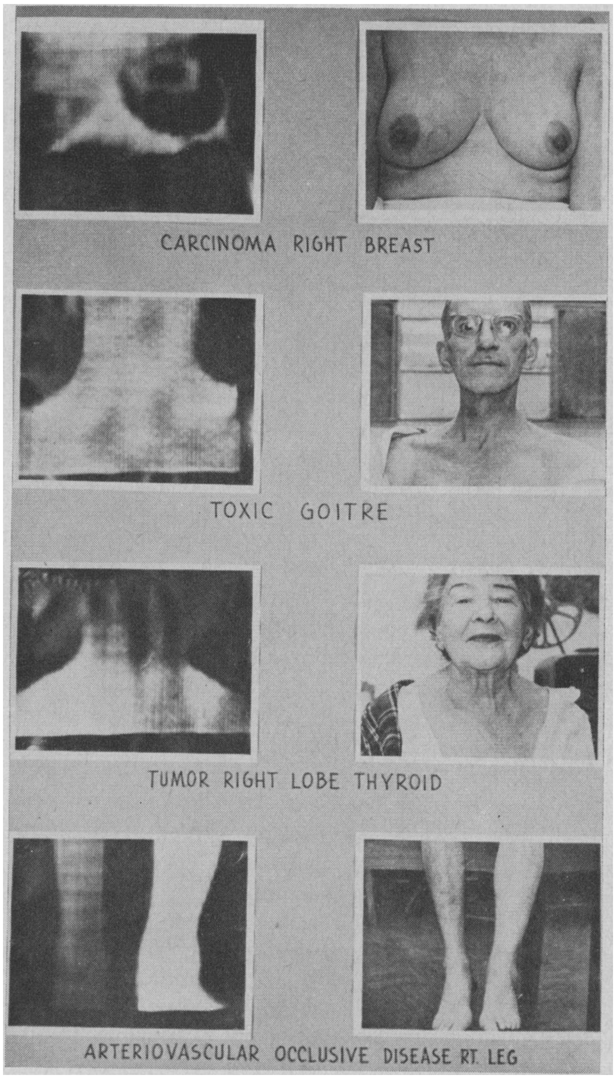

Fig. 1.—Examples of various clinical states that show abnormalities in heat radiation. The left column contains infrared images and the right column corresponding black-and-white photographs. The infrared images are varying shades between light and dark which are proportionate to the heat radiated: warmer areas are lighter; colder areas, darker. The various shades of grey can be translated into actual temperatures. In the top picture of breast cancer, the skin area overlying the tumour is warmer than the surrounding area owing to the increased heat from tumour growth. Furthermore, the right breast as a whole is considerably warmer than the left breast. In the case of the toxic goitre with its increased circulation and metabolic activity, there is marked increase in heat radiated, not only from the area of the thyroid, but the surrounding neck structures. In the third picture down, there was a large malignant thyroid adenoma of the right lobe. This is depicted by a decidedly raised temperature in the region. The right leg in the bottom picture is particularly ischemic. The decrease in the skin temperature can be quantitatively measured by the infrared image.

speed of infrared radiation, the fact that it cannot be jammed like radar, and certain other qualities make it a desirable military tool for the detection of oncoming guided missiles. The core of the technical problem of employing invisible infrared patterns for medical use is their conversion into something that can be easily and accurately interpreted by the naked eye. This may be accomplished by producing a black-and-white image (with intermediate shades of grey) that corresponds to the heat patterns being emitted on a television type of tube or polaroid photographic film. Such an infrared picture is just as different from the common,

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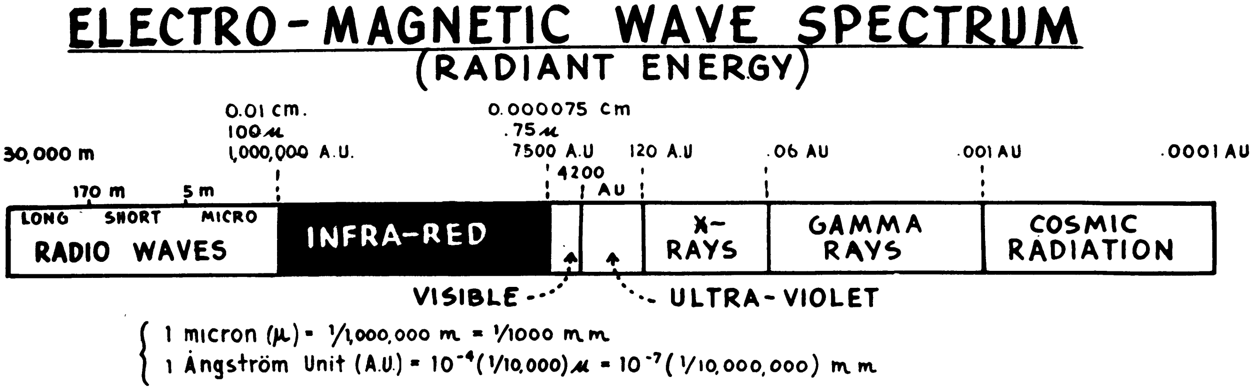

Fig. 2. — Electromagnetic wave spectrum (radiant energy).

everyday black-and-white photograph of the visual spectrum as is an x-ray image. A developed x-ray film is strictly a record of densities. This type of infrared picture, which we call a "thermogram", unlike an infrared photograph, is solely a record of radiated heat. If some type of barrier is placed in front of a source of heat, it will interfere with the outward passage of heat radiation. The object acting as a barrier will reflect some heat back, absorb some and lose some by conduction. In turn it will radiate the residual, lesser amount of energy. Any object with a temperature above minus 273° C. will emit heat waves from its surface. At absolute zero all molecular motion ceases. Therefore, every material substance with which we are normally in daily contact radiates energy in the infrared portion of the electromagnetic spectrum. Human skin emits radiation in the intermediate infrared spectral region, 3-15 μ. The maximum or peak radiation wave lengths are from 9-10 μ in length. Since the emissivity of the skin is very near that of a blackbody radiator, the amount of radiation emitted from an area depends on the actual temperature of that area.

It appeared that the above principles might be applied to the assessment of thermal injuries. Destroyed or devitalized skin might presumably act as a barrier and thus interfere with heat radiation, whereas partially burned skin, which retains its vitality, might emit more than the normal amount of heat because of the surface inflammatory changes associated with increased circulation and metabolism at the cellular level.

To test this premise, infrared observations on burns and frostbite injuries were made. Our imaging device has an optical system which focuses an incoming beam of heat radiation by parabolic mirrors on to a detector cell composed of indium antimonide (Fig. 3). The electrical conductivity of indium antimonide is exquisitely and specifically sensitive to minute alterations in infrared radiation, particularly when maintained near minus 78° C. Just in front of this detector cell a blade rotates at high speed to interrupt or chop the incoming beam of electromagnetic waves. In this way, a small current across the cell is made to pulsate. This pulsating current lends itself to any desired degree of electronic amplification. For our purposes it is amplified enough to modulate a glow tube which continuously scans across a polaroid film, or, with more modern equipment, to control the brightness of a cathode ray storage tube. Thus, on the surface being studied, the warmer areas which emit more infrared radiation, cause increased brilliance of the glow tube and are depicted on the ultimate visual display as lighter areas. The position of the glow tube light on the film is in a one to one correspond-

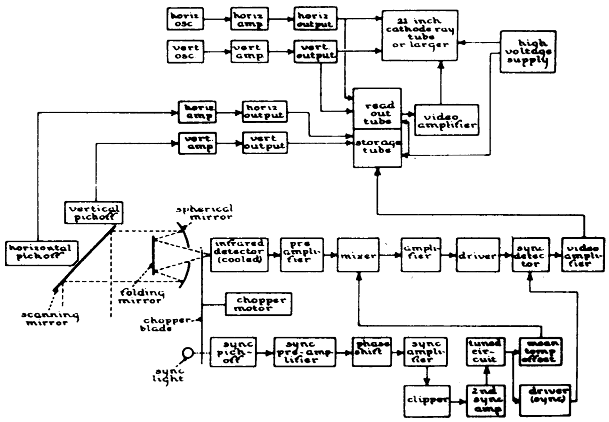

Fig. 3.—Block diagram of infrared sensing device (scanner).

ence with a small spot on the emitting skin, so that, in automatically scanning this skin, a thermal map of the surface is produced to give large or very small (down to 0.1° C.) temperature ranges between black and white. The image can be stored on either magnetic tape or film for future comparison. Known temperature sources can be incorporated into every image for reference purposes. However, a great many technical problems associated with physiology and environmental controls still remain to be studied in conjunction with these new infrared scanners.

METHOD

Healthy, adult dogs were anesthetized, shaved on the side and then exposed serially for 5, 10, 15 and 20 seconds to an ordinary commercial infrared lamp at 24 cm. distance. Control areas were shielded with tinfoil. Serial thermograms (radiated

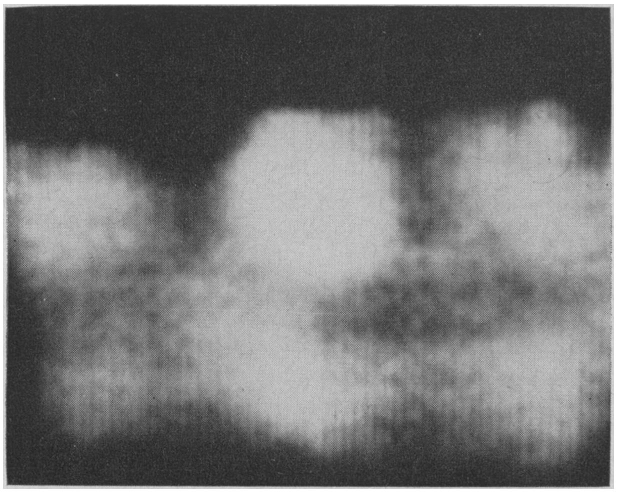

Fig. 4.—Thermography of dog's skin showing six burns 15 minutes after infliction of burn injury.

heat images) were obtained up to 24 hours after injury (Figs. 4 and 5). At that time histological sections were taken of the lesions and stained with hematoxylin and eosin and then given a second treatment with Verhoff's elastic tissue stain. This technique is satisfactory for microscopic evaluation of the depth and degree of dermal destruction. Fifty-five burns of varying degrees were studied at 24 hours. Positive thermographic correlations were obtained in 50. In three instances the infrared patterns were typical of third-degree burns but histological studies showed that full thickness destruction was not complete. In two burns the infrared display was that of incomplete skin destruction, but the histological findings signified third-degree burning.

Next, 27 frostbite injuries of varying degrees were produced by the direct application of dry ice to shaved dog skin (Fig. 6). The lesions were examined by the same technique and observed for a period of seven days. Gangrene was produced in 22, but not in five. In all instances the thermographic assessments were correct. Following cold injuries a

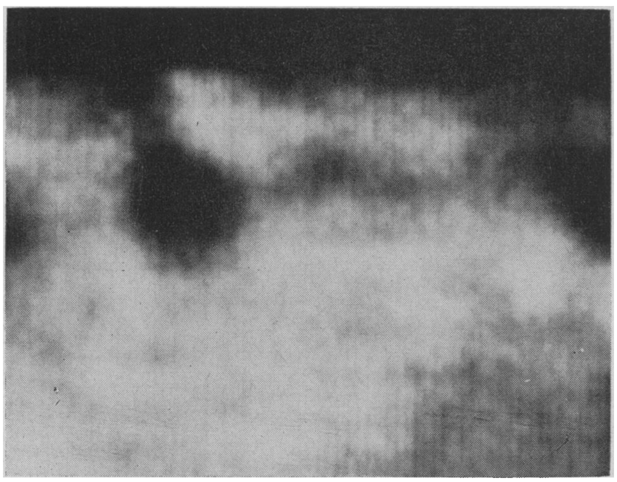

Fig. 5.—Thermography of dog's skin 24 hours after burn, showing two areas of decreased skin temperature (black) that represent full-thickness burns.

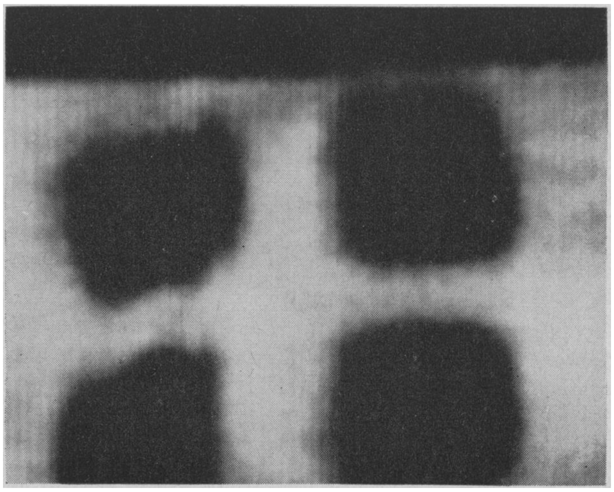

Fig. 6.—Thermography of dog's skin 1 minute after the infliction of four equal frostbite injuries.

period of increased skin temperature was observed prior to the cooling which heralded the onset of gangrene. With some experience with the device, it was possible to predict accurately *all* the cold lesions which would become gangrenous.

CONCLUSION

Infrared scanning was accurate in predicting the depth of 90% of 55 dermal burns in 24 hours. The method was reliable in predicting the onset of gangrene in all 27 frostbite injuries of the skin.

The results obtained warrant further intensive exploration to determine the scope of this new technique in biological measurement.

Many other clinical applications of this development from the missile and space programs are awaiting evaluation. Investigators with sufficient knowledge, interest and financial support are needed to bridge this gap between the ivory tower and the patient.

SUMMARY

In this short communication we have discussed a new technique in temperature measurement. In spite of the fact that the infrared equipment used for these observations has now become relatively crude and obsolescent, a high degree of accuracy was obtained in evaluating both the depth and area of skin destruction due to either heat or cold injuries. We feel that the small percentage of error will be significantly reduced with improved technical equipment.

REFERENCES

1. LAWSON, R.: *Canad. M. A. J.*, **75**: 309, 1956.
2. *Idem*: *Ibid.*, **79**: 402, 1958.
3. WILLIAMS, K. L., WILLIAMS, F. L. AND HANDLEY, R. S.: *Lancet*, **2**: 958, 1960.