Ocular thermography

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The surface temperature of the eye or periorbital skin can be determined by contact or by measuring the quantity of radiation emitted (Mapstone, 1968). The latter method is in practice more convenient and accurate, using an instrument such as a bolometer, which records temperature directly on a dial, or an infrared imaging device that produces a thermal picture. The purpose of this paper is to describe the thermographic patterns that occur in normal, ischaemic, and hyperaemic ocular states, using an infrared camera.

Material and methods

The camera used was a Bofors infrared; air temperature was measured with an air thermistor probe, and the usual precautions taken before each measurement (Mapstone, 1968).

The Bofors system consists of a camera unit and display unit (Fig. 1). The former scans the object and an indium-antimonide detector registers a thermal picture which is reproduced on an oscilloscope and can be photographed for a permanent record. The reproduction consists of a "grey tone" picture with hot areas appearing white, and progressively colder areas grey, to the coldest black.

In addition, areas of equal temperature (in this paper within $0.125^{\circ}\text{C}.$) can be mapped by producing isotherm images. These appear on the picture as an area of high intensity white, and by shifting an isotherm band – with the display unit controls – from one area to another, the temperature difference between these areas can be calculated. It is claimed that points 2 mm. apart can be resolved by the camera and that thermal resolution is better than $0.2^{\circ}\text{C}.$ with a black body radiator.

The normal picture described is that based on a scan of thirty subjects. The abnormal pictures are from patients with anterior uveitis, internal carotid stenosis, and ischaemic anterior segments.

FIG. 1 *Infrared camera and display unit*

Results

A normal ocular thermogram is shown in Fig. 2. Taking this as a model, isotherm bands are introduced in Fig. 3 so that areas within 0.125°C . of each other appear as bright white areas. Fig. 3 is the base-line temperature from which (in this example) temperature differences are measured so that, as the isotherm is moved to cover areas of higher temperature, the area included within the band – and black on the picture – increases (*cf.* the cold nasal areas between Figs 3 and 4 where the isotherm has moved 0.5°C .). Between each of Figs 3 to 7 the isotherm has moved 0.5°C ., so that, for example, the bright areas in Fig. 7 are 2°C . hotter than those in Fig. 3.

FIG. 2 Normal ocular thermogram: cold areas black, hotter areas grey to white

FIG. 3 Same as Fig. 2, with isotherm band introduced. This is the base temperature from which succeeding temperature differences are measured

FIG. 4 Same as Fig. 3, with isotherm moved $+0.5^{\circ}\text{C}$.

FIG. 5 Same as Fig. 4, with isotherm moved $+0.5^{\circ}\text{C}$.

Fig. 2 shows that the normal thermogram has the following characteristics:

- (A) Relatively cold areas
 - (1) Eyebrow
 - (2) Cornea and a variable area extending onto the conjunctiva medially and laterally
 - (3) Tarsal portion of upper and lower lid
- (B) Relatively hot areas
 - (1) Medial and lateral canthi
 - (2) Medial and lateral palpebral skin
 - (3) Orbital part of lid skin joining the two former areas

The coldest areas are the eyebrows and tarsal upper lid (Fig. 3). 0.5°C . hotter (Fig. 4) is an area including the approximate centre of the cornea and strip along the lower lid. In this subject the corneae are of almost equal temperature, and as the isotherm is moved to enclose the whole of the cornea (Fig. 5), the topographical variation in surface temperature is 0.5 to 1°C . The hotter areas become progressively encroached upon, until (Fig. 7) 2°C . from the base isotherm, the only areas remaining outside are canthal skin, small areas of conjunctiva, and orbital lid skin. Finally, lateral palpebral skin is included followed by medial, the difference between hottest and coldest areas being in some subjects up to 5°C . Minor variations in normal pattern from the above do occur, but the one described is the commonest.

FIG. 6 Same as Fig. 5, with isotherm moved $+0.5^{\circ}\text{C}$.

FIG. 7 Same as Fig. 6, with isotherm moved $+0.5^{\circ}\text{C}$.

Fig. 8 is a thermogram from a patient with unilateral anterior uveitis (R). The contrast between the two eyes is apparent and, in addition to a hotter cornea, adjacent conjunctiva and palpebral skin are also involved (corneal temperature differences were 0.9°C ., measured with a bolometer).

Fig. 9 shows a patient with right unilateral ischaemic anterior segment. Fig. 10 also shows a patient with an ischaemic anterior segment, but in addition there is a patch of cold medial forehead skin, *i.e.* the ischaemia is due to carotid artery pathology, whereas in the case shown in Fig. 9 it was caused by antecedent recurrent uveitis.

FIG. 8 Thermogram of patient with right anterior uveitis

FIG. 9 Thermogram of patient with right ischaemic anterior segment (right cornea colder than left)

FIG. 10 *Thermogram of patient with right internal carotid stenosis (right cornea and right medial forehead-skin colder than left)*

Discussion

The thermal patterns in and around the eye can be explained as follows: surface heat is lost by convection and radiation; convected loss depends on a free passage of air over a surface, and if this is plane or convex there will be no impediment to flow, whereas with a concave surface isolated pockets of skin will form a quiet backwater. With radiant loss surface skin, if plane or convex, radiates at a temperature of 30 to 35°C. to an ambient of around 20°C. so that a net loss occurs. A concave surface, however, will cross-radiate some of its heat between the walls of the concavity, which have similar temperatures so that – depending on the degree of concavity – a lesser net loss of heat occurs. Hence convex/plane surfaces – cornea and tarsal lid – are colder than medial and lateral canthi, the latter – being most concave – being hottest of all.

Local blood supply is also a factor in that cornea and hairs are avascular – but the suprising fact is not that the cornea is relatively cold, but rather that it is so hot. Finally, the upper lid blink creates a draught over its surface and the globe so that this too contributes to their relative coldness.

Figs 9 and 10 underline the necessity, when assessing an ischaemic anterior segment, of measuring medial forehead skin temperature, since some, or all, of the ischaemia may be due to more proximal pathology in the carotid tree.

The topographical variation in corneal temperature illustrates the unreliability of contact thermometry, whilst at the same time showing the value of a bolometer in measuring the temperature of an area. The proximity of the latter, however, can produce tearing which destroys thermal equilibrium so that, if further temperature readings are required, re-equilibration becomes necessary. An infrared camera has none of these disadvantages and, in addition, rapidly allows the surface thermal pattern to be seen, which may in certain circumstances be more revealing than absolute temperature differences.

Summary

The infrared images produced by the eye and periorbital skin in normal and abnormal subjects are described.

The patterns are explained and the advantages of infrared cameras briefly discussed.

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References

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