

Use of Digital Infrared Imaging to Objectively Assess Thermal Abnormalities in the Human Eye

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● We have developed a specialized ophthalmological infrared camera and software that allow quantitative objective analysis of computerized thermal images of the human eye. Using these tools, we have studied the effects of rubbing and pressing the eye on the reproducibility of corneal temperature distribution. We collected data to help establish a protocol for thermographic ophthalmologic examinations. We also quantitatively compared the temperature distribution over the corneas of patients who wear contact lenses with those in patients who do not. Corneas of patients who wear contact lenses over a prolonged period show statistically significant increases in thermal irregularities.

Introduction

The temperature of the cornea has long interested ophthalmologists, who have used different techniques to measure it. Since the eye loses heat through the cornea, the temperature of the cornea is a function of the internal temperature of the eye. In addition, local processes involving the cornea may manifest as changes of local temperature. The use of infrared thermal imaging to monitor the cornea's temperature dates back to 1970.¹⁻³ Scanning infrared cameras were thus introduced into ophthalmology 40 years after the pioneering study of Zeiss,⁴ who measured the corneal temperature using a radiative, noncontact procedure instead of one of the less reliable contact methods. This was followed by several studies using infrared single-spot temperature measurements (for example, see Refs. 5 & 6). It is surprising that in spite of the availability and demonstration of these noncontact temperature-measurement methods, contact measurement of the cornea continued to be used until the mid-1980s.^{7,8}

Although many fundamental features of the thermophysiology of the eye have been explored, relatively few routine thermometric or thermographic ophthalmological applications have been reported. Fewer than 70 papers on temperature measurements in the eye have been published worldwide in the period 1964-80. More than half of these were animal studies and papers on the gross vascular supply to the head. This leaves less

than 3 papers per year for clinical studies of the eye. Activity in this field did not increase in the 1980s with the advent of faster and more reliable remote sensing infrared scanning cameras. In the period 1980-85, less than 5 papers per year were published worldwide; less than 2 per year in the United States and Britain combined.⁹ This low rate of research activity even decreased between 1986 and 1990.

The reason for the sparse use of thermal imaging of the eye in ophthalmology is not a lack of interesting problems or worthwhile applications. Thermal mapping of the cornea has been known and discussed for decades and several meaningful clinical uses have been suggested.⁹ On the other hand, Grove's review in 1975 states: "Thermography seldom provides a diagnosis of orbital disease that is not apparent by other readily available technics. Because it is completely innocuous and noninvasive, it deserves further study and evaluation."¹⁰ We believe that the main reason for its rare use has been the lack of instrumentation that can provide reliable data amenable to objective interpretation.

When we started our ophthalmological thermal imaging studies three years ago, we realized that to make it a useful diagnostic technique one must meet three basic requirements: First, one needs a remote computerized thermal imaging device with a linear resolution of <0.2 mm on the image of the cornea, with a thermal resolution of <0.1°C. Second, because the cornea encompasses such a small area, one must precisely correlate its thermal image with its anatomy. Third, to make thermal imaging of the eye diagnostically useful, one needs objective quantitative measures of the thermal information. All these objectives have now been achieved, as described in this paper.

We developed a special-purpose ophthalmological computerized thermal imaging camera with the appropriate software to handle images of the eye. Using these new tools, we assessed the scope and limitations of a diagnostic protocol. In developing a reliable and reproducible diagnostic protocol, we studied the effects on the thermal image of time and of rubbing one eye before measurement. We found that these parameters do not significantly affect the diagnostic information. As a first

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