Role of body temperature in the definition of retinal burn threshold

Brian Ward and W. Robert Bruce

Young adult rhesus monkeys were anesthetized with a barbiturate which dislocates the normal thermoregulatory mechanism. The core temperature was then controlled by a heating pad, and the chorioretinal burn threshold was determined for different temperatures with the use of light from a Zeiss photocoagulator. The results show linear relationships between the threshold retinal irradiances and body temperature for two different sets of exposure parameters. Extrapolation of the two sets of data provides an estimate of the critical temperature for production of the threshold chorioretinal lesion. The roles of body temperature and certain exposure parameters in the production of retinal damage are discussed.

Key words: ocular burn, thermal damage, photocoagulation, eclipse blindness, light damage, infrared, retina, choroid, core temperature

It has been shown in a preliminary report that the irradiance threshold for a chorioretinal burn is an inverse linear function of core temperature between 34°C and 39°C in the rhesus monkey. Making certain assumptions, it was possible to make inferences on the critical tissue damage temperature for the threshold burn criteria used. Further studies have been conducted to test the validity of the previous results, for different retinal irradiance parameters, in young adult rhesus monkeys.

Materials and methods

A specially modified Zeiss photocoagulator was used to produce just-visible chorioretinal lesions in rhesus monkeys. The irradiated geometric area subtended 1.5 degrees at the nodal point of the eye, with an exposure time of 100 msec. Fig. 1 is an optical diagram of the photocoagulator system. Light from the xenon arc is reflected from the concave mirror and focused back in the plane of the arc. The condenser lens then images the arc at the image field stop. The iris diaphragm is used to control the image field irradiance. The infrared content of the beam is reduced by a KG-3 filter. The arc’s image at the image field stop is at the focal point of the final lens and is brought to a focus on the retina by the optics of the emmetropic eye. The area of the retina irradiated is controlled by the size of the image field stop. The mirror, which directs the beam into the eye, is interposed after the firing sequence has been initiated, but before the opening of the shutter which controls the exposure time. The aiming of the beam is accomplished by the use of an ophthalmoscope which projects cross-hairs onto the fundus ocular. The mirror is linked mechanically to the ophthalmoscope and aligned so that, when the shutter opens, exposure occurs at the site at which the cross-hairs were positioned.

The animals were anesthetized with pentobarbital sodium (Nembutal), intravenously, for...
the data collection procedure. In order to minimize the disturbance of corneal clarity, mydriasis was effected by instilling atropine sulfate in both eyes on the day prior to data collection. The animal's core temperature was monitored continuously by means of a rectal thermistor and was controlled with a heating pad wrapped around the body.

The animal's eyes were kept closed except during the lesion threshold determinations. The damage criterion employed was the appearance of an ophthalmoscopically detectable fundus change within five minutes of the exposure. Threshold fundus changes, detectable with the direct ophthalmoscope, consist of a slight greying, a fundus-ground texture change, and changes in the retinal reflex in the area irradiated. Satisfactory corneal transparency was obtained by the irrigation of the eye with artificial tears, when necessary, and by ensuring that the lids were closed whenever possible. It was found to be easier to maintain corneal transparency at the higher core temperatures. The animals were found to require increased dosages of the anesthetic to maintain a comparable level of anesthesia at the higher core temperatures.

Corneal irradiance was determined from an oscilloscope trace of the output of a calibrated photodiode. Calculations of the corresponding retinal irradiances made use of optical constants appropriate for the rhesus monkey eye. All the eyes were within ±0.5 diopters of emmetropia in any meridian. Irradiance thresholds were determined in terms of the smallest burn/no-burn ranges obtained by bracketing. The adjustable iris diaphragm and calibrated neutral density filters were used to determine the lowest irradiance for which a lesion was produced and the highest irradiance for which no lesion appeared within five minutes of the exposure being made. Determinations of the chorioretinal burn threshold were made for each eye at at least two core temperatures. Both ascending and descending core temperature series were employed.

The unit of retinal irradiance used (cal.sec⁻¹.cm⁻²) represents a measurement of corneal irradiance modified by a factor derived from the geometry of the beam entering the eye and from optical constants of the rhesus monkey's eye. Retinal burn data are normally reported in such units because of the present lack of suitable techniques for the direct accurate measurement of retinal irradiance or of its local thermal effects.

Results

Fig. 2 presents the results of this study (upper data points) along with replotted data from an earlier study which involved chorioretinal burn threshold determinations for 500 msec. exposures in circular areas subtending 3 degrees at the nodal point of the eye (lower data points). Greater scatter is seen in the threshold data involving the shorter exposure times and smaller retinal areas. At all the core temperatures examined, higher retinal irradiances were required to produce the threshold chorioretinal lesion with the shorter time exposure. This effect became less as core temperature was increased. Such a finding is consistent with the view that, at the higher body temperatures, a smaller proportion of the thermal energy producing the threshold lesion was of radiant origin. On this basis,
the curves would be expected to intersect on the abscissa at the tissue temperature associated with the production of a lesion meeting the defined threshold criteria. Least-squares fits to the data presented in Fig. 2 give lines which extrapolate to indicate critical temperatures for production of the threshold lesion of 43° C. to 44° C.

Little difference is expected between the threshold irradiances for circular retinal areas of 1.5 degree and 3.0 degree subtense. However, the 100 msec. exposures would be expected to produce higher irradiance thresholds than do the 500 msec. exposures, because these times are short enough to alter significantly the thermal result of the energy delivered to the tissue. If the critical temperature for the production of a particular lesion is fixed, it will be possible to produce an approximate curve for a new set of exposure parameters by making an experimental threshold determination at one core temperature and drawing a line through the two points.

Since few data are available on the relationships between the optical and thermal properties of the eye and core temperature, it is not possible to consider such effects upon the retinal burn threshold. However, the critical temperatures inferred in this study fall within the range associated with cell protein changes.

The reported results confirm the earlier
findings and indicate the importance of considering core temperature in the definition of retinal burn threshold. Low retinal irradiance thresholds at low core temperatures indicate correspondingly lower thresholds at elevated core temperatures. Any connection between body temperature and chorioretinal burn threshold, from exposure to the sun or to artificial sources of visible or infrared radiation, has implications in the fields of clinical ophthalmology and preventative and industrial medicine.

REFERENCES