Ocular Hypothermia Depresses the Human Pupillary Light Reflex

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Twelve human volunteers were studied to determine the effect of eye surface cooling on the parameters of the light reflex. Surface cooling resulted in a 38% decrease in the maximum constriction velocity and a 36% decrease in the maximum redilation velocity. These changes were thought to be the result of a “sluggish” response of the pupillary sphincter. Invest Ophthalmol Vis Sci 32:3285–3287, 1991

Profound hypothermia is known to depress the pupillary light reflex, but the mechanism of this action is unknown. We recently concluded a study showing that mild central hypothermia (1.6 ± 0.3°C below normal) did not depress the light reflex appreciably. These results led us to suspect that the effect of profound hypothermia on the light reflex may involve, in part, the pupillary sphincter, eg, cooling of the iris musculature may interfere with the speed at which the constrictor muscle can respond to a neural stimulus. To test this hypothesis, we studied the effect of local eye surface cooling on the human pupillary light reflex, using an infrared pupillometer.

Materials and Methods

With approval from the Committee on Human Research at the University of California, San Francisco, and written informed consent, we studied 12 volunteers. All were men (age range, 20–50 yr) who were healthy without any eye disease. The subjects were placed supine in a dimly lit room (150 lux) and allowed to relax for 15–30 min. Control pupillary measurements then were taken using a portable infrared pupillometer with a 0.5-sec stimulus and a 2-sec scan. This instrument takes approximately 5 sec to focus; therefore, each measurement required 7–10 sec. Stimulus intensity was 130 cd/m². All scans were taken from the right eye. The subjects focused on the eye of the examiner, a distance of approximately 60 cm.

The volunteers were divided randomly into two groups of six each. In the first group (group 1), the light reflex was measured during a 10-min control period; then a 4-oz plastic bag containing water at 36°C was placed for 4 min on the eyelid of the closed right eye. The water bag was removed, and the light reflex responses were measured again within the first min. At least three scans were taken during this time, and the bag was reapplied after each scan. The eye then was left uncovered for 10 min, and the scans were repeated.

Pupillary reflexes in group 2 were measured similarly except the water bag was replaced by a 4-oz plastic bag of chopped ice at 0°C. If the ice bag became uncomfortable, the volunteer was permitted to remove the bag for a few seconds and then reapply it.

In both groups, corneal temperatures were recorded after each pupillary measurement with an infrared surface temperature scanner (Exergen, Newton, MA) positioned within 1–2 mm of the cornea. At least three individual scans were obtained during each measurement period and averaged to provide a single scan for each period. The averaged scan was analyzed for pupillary size, maximum constriction velocity, maximum redilation velocity, and reflex amplitude. Temperature measurements for each period also were averaged, then assigned to the corresponding averaged scan taken over the same period.

Our results are reported as the mean ± the standard deviation. Measurements in the same subjects before treatment were paired with measurements after treatment (water or ice bag), and then they were analyzed statistically using the student t-test for paired data. A P value of <0.05 was accepted as significant.

Results

The pertinent data are shown in Table 1. The corneal temperature did not change in group 1 (water bag) but was decreased 3.9 ± 0.6°C in group 2 (ice
Table 1. Parameters of the light reflex and temperature changes in both groups before and after treatment

<table>
<thead>
<tr>
<th></th>
<th>Eye surface temperature (°C)</th>
<th>Pupil diameter (mm)</th>
<th>Reflex amplitude (mm)</th>
<th>Maximum constriction velocity (mm/sec)</th>
<th>Maximum redilation velocity (mm/sec)</th>
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</thead>
<tbody>
<tr>
<td><strong>Group 1 (water)</strong></td>
<td></td>
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<tr>
<td>Before</td>
<td>34.3 ± 0.5</td>
<td>5.5 ± 1.1</td>
<td>1.9 ± 0.3</td>
<td>5.2 ± 0.8</td>
<td>1.9 ± 0.4</td>
</tr>
<tr>
<td>After</td>
<td>34.5 ± 0.6</td>
<td>4.9 ± 1.2*</td>
<td>1.8 ± 0.3</td>
<td>5.1 ± 0.8</td>
<td>2.2 ± 0.4</td>
</tr>
<tr>
<td>Recovery</td>
<td>34.3 ± 0.6</td>
<td>5.4 ± 1.2</td>
<td>1.9 ± 0.2</td>
<td>5.4 ± 0.6</td>
<td>1.9 ± 0.3</td>
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<tr>
<td><strong>Group 2 (ice)</strong></td>
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<tr>
<td>Before</td>
<td>33.8 ± 0.5</td>
<td>5.6 ± 1.3</td>
<td>1.9 ± 0.4</td>
<td>5.2 ± 0.8</td>
<td>2.2 ± 0.4</td>
</tr>
<tr>
<td>After</td>
<td>29.9 ± 0.6†</td>
<td>4.8 ± 1.5†</td>
<td>1.5 ± 0.5†</td>
<td>3.1 ± 1.1†</td>
<td>1.4 ± 0.2†</td>
</tr>
<tr>
<td>Recovery</td>
<td>33.2 ± 0.5</td>
<td>5.1 ± 1.1</td>
<td>1.9 ± 0.5</td>
<td>5.2 ± 1.3</td>
<td>2.1 ± 0.6</td>
</tr>
</tbody>
</table>

* P < 0.01 compared to values of same group before treatment.
† P < 0.001 compared to values of same group before treatment.

Pupil size diminished similarly in both groups. Cooling the eye significantly reduced the dynamic properties of the pupillary light reflex; ie, both maximum constriction velocity and maximum redilation velocity were reduced significantly (Table 1). The changes observed in both groups were reversed 10 min after the water or ice bag was removed. The changes observed in the light reflex response were consistent in each subject. Pupil size did not change in one volunteer in each group. Composite scans for the two groups are shown in Figure 1.

**Discussion**

We believe our data show that surface cooling of the eye decreases the speed at which the pupil constricts and relaxes in response to a light stimulus. It might be argued that other factors, such as pressure from the bag, exclusion of light from the retina, or a decrease in pupil size, might account for the changes we observed. In our opinion, these were excluded as causative factors by our control group (group 1) who were treated similarly to the study group (group 2) with the exception of the surface cooling. These control volunteers did not respond during the testing period with reflexes that were depressed. From a previous study, it is known that a light reflex of 1.5-mm amplitude should have a maximum constriction velocity of approximately 4.5 mm/sec. The maximum constriction velocity of the light reflex in our group 2 (cold eye) volunteers was 3.1 ± 1.1 mm, outside the 95% confidence limits reported for a 1.5-mm reflex. All other reflexes in our study showed normal constriction velocities in relation to their reflex amplitudes. We conclude that local cooling of the corneal surface produces a "sluggish" light reflex.

It is known that victims of cold exposure have diminished or absent light reflexes, but the mechanism of this depression has not been studied to our knowledge. The components of the light reflex consist of the receptor (retina), the central neural mechanism (pre-tectal and pupilloconstrictor nucleus), the ciliary ganglion, and the peripheral neuromuscular apparatus (iris). Because the iris is closest to the surface, it is likely that this structure would be affected more profoundly by surface cooling than more centrally located structures such as the synaptic connections in the retina and the midbrain. The decreased temperature of the iris in our subjects whose eyes were cooled probably was less than the 3.9 ± 0.6°C decrease recorded at the cornea, and this reduction would be even less at structures further from the body's surface. Although it is possible that these central structures were cooled and thus depressed in our cooled group, it seems unlikely that surface cooling for only a few minutes would lower the retinal or midbrain temperature enough to depress these structures. Our
cooled group did not report any diminution in the strength of the light stimulus, and there was no subjective change in vision from the local cooling. Both the midbrain and the retina are highly vascular structures that are insulated effectively from changes in ambient temperature by the numerous bony sinuses that surround them. Central hypothermia is therefore an unlikely explanation for the observed depression of the light reflex in our subjects.

Muscular contraction depends on enzymatic processes that are highly temperature dependent. We observed a more marked decrease in the dynamic measurements of contraction (maximum constriction velocity and maximum redilation velocity) compared with the static parameters (pupil size and absolute reflex amplitude). Cooling of skeletal muscle is known to reduce both the rate of contraction and the rate of relaxation, but the effect of hypothermia on the contraction speed of smooth muscle is unknown.

During resuscitation from cold exposure, the light reflex is often reduced or absent. Because a surface-to-core temperature gradient would be expected in victims of cold exposure, the iris musculature (surface structure) would be more hypothermic than the midbrain reflex centers (core structure). Our study showed that local cooling of the eye surface has a profound depressant effect on the light reflex. It thus appears that warming of the iris must be accomplished before the light reflex can be used as a prognostic sign during resuscitation from cold exposure. If the eye remains hypothermic during the rewarming period, the light reflex would be absent or sluggish until the eye temperature returns to normal.

**Key words:** pupil, light reflex, hypothermia, resuscitation

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**References**