functions would have resembled W. H.'s data in the parafovea and F. A.'s data in the periphery; that is, the difference between LAC and DAC thresholds would have increased monotonically with eccentricity.

I thank Mary Hayhoe, Louise Sloan, Kenneth Fuld, and Carl Ingling for helpful comments on earlier versions of the manuscript, and William Huppert and Fareed Artnaly for technical assistance.


Key words: cone threshold, retinal eccentricity, dark adaptation

REFERENCE


Clinical method for measurement of light backscattering from the in vivo human lens. I. BEN-SIRA, D. WEINBERGER, J. BODENHEIMER, AND Y. YASSUR.

A simple clinical method for measurement of light backscatter from defined regions of the lens in vivo is described. Light scattering was quantitated in 168 lenses of 85 "normal" subjects spanning 8 decades of life. The results indicate that light scatter from the anterior capsule does not change with age. The light scatter from the anterior cortex is quite significant even in young lenses and gradually increases with age. The backscatter in the nuclear region is minimal in young eyes, increasing gradually up to the age of 40, after which it exhibits a sharp increase.

Recent advances have contributed to our understanding of the clouding and eventual opacification of the lens which constitute cataract formation. It has been proposed that the formation of protein aggregates in the lens leads to local differences in the index of refraction and produces scattering of the light incident on the lens. Light scattering is the main cause of disturbances of vision seen in aging people, such as increased glare sensitivity, decreased contrast sensitivity, and reduction of visual acuity.

A major difficulty in documenting the development of a cataract has been the absence of an objective clinical quantitative method for determining the optical changes within the lens. A number of investigators have developed quantitative methods for the measurement of lens opacification or light scattering. Goldmann has described an instrument, which is a modified slit lamp, in which part of the illuminator's beam is branched off and reflected through a small glass plate in the ocular. This comparison light serves as a reference light. With this method he obtained data about the light scattering by the central part of the lens in relation to age. Wolf and Gardiner measured the scatter of light in the whole lens. In their photometric method the brightness of a stabilized light source incorporated into a modified slit lamp is compared to that of the backscattered light from the posterior part of the lens. Brown and later Sigelman et al. performed microdensitometry of slit-lamp photographic negatives of the lens. The method used by us is similar to that of Goldmann in that a constant part of the light coming from the standard slit lamp is used as the reference instead of incorporating an expensive stabilized light source. In addition, we measure light.
Fig. 2. Opacity value of light backscatter from the anterior capsule, anterior cortex, and the nucleus in various age groups. •, Two eyes examined in same patient; ▼, One eye examined.

<table>
<thead>
<tr>
<th>Age</th>
<th>No. of patients</th>
<th>No. of eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Up to 10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2. 11-20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>3. 21-30</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>4. 31-40</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>5. 41-50</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>6. 51-60</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>7. 61-70</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>8. 71-80</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>168</td>
</tr>
</tbody>
</table>

scatter from localized areas of the lens rather than from the whole lens.

Material and methods. The instrument (manufactured by Laser Industries, P.O. Box 13135, Tel-Aviv, Israel; price (subject to change) $1,350.00 in U.S. currency) is basically similar to the Tyndall photometer described by Blumenthal et al. and is similarly mounted as a compact unit on a Haag-Streit Model 900 slit lamp (Fig. 1). The detection angle is 40° relative to the incident beam. The "red-free" filter of the slit lamp is used to avoid the color shift caused by scatter when polychromatic light is employed. The instrument provides a reference light patch within the microscope field of view, which is adjacent to the region of the lens to be measured. The brightness of the reference patch can be adjusted until it matches the brightness of the backscattered beam in the region being examined. The position of the reference can be shifted within the field view to appear immediately above or below the region being tested. The "opacity value" is given as a number between 1 to 10. Each step corresponds to an optical density increment of D = 0.15, which is well above the visual discrimination threshold for two adjacent regions. The measured values at any certain point are independent of variations in slit height, width, or brightness and have been obtained consistently by different observers using all possible slit conditions. Since "normal" lenses without variation in opacities were observed in this study, a slit beam 0.1 mm in width and 3 mm in length was selected.

The 85 subjects, all of whom had a visual acuity of 6/6 as evaluated with an American Optical Projector, were divided into eight groups according to age (Table I). In addition, each subject had a fundus and slit-lamp examination, and any eye showing abnormality was excluded from the study. Examination was performed in a dark room with the patient’s eyes fully dilated by a topical solution.
of 10% phenylephrine. Each lens was examined several times by two different observers. There was an excellent consistency of the opacity score between the two observers.

**Results.** The score of the opacity values in the capsule, cortex, and nuclear regions in the various age groups is given in Fig. 2. It is evident that there was no significant change in light scatter from the anterior capsule with aging. The light scatter from the anterior cortex was significant even in young lenses, and a gradual increase was observed with aging. In the nuclear region the backscatter was minimal in young eyes, exhibited a gradual increase up to the age of 40, and thereafter increased more rapidly.

**Discussion.** The quantity measured by our method is the image luminance of the backscattered beam. As the incident slit beam passes through the lens, it is partially scattered by the lens. Some of the backscattered light (the "object") is collected by the slit-lamp microscope objective, and a conjugate image of the object is formed, which is observed through the eyepiece. In accordance with basic laws of radiometry, the image luminance equals the object luminance except for attenuation due to the absorption, reflection, and scatter which occur between the object and image. The attenuation occurring outside the lens is a minor problem because it is constant. Attenuation, however, also occurs within the lens due to imperfect transmission by the lens itself. The luminous flux of the incident beam decreases as it passes through the lens, thus causing a weaker object luminance, and the backscattered light is again attenuated by the lens. When we consider that these factors depend on the very quantity being measured, i.e., the lens opacity, we realize the complexity of the problem. Thus a low opacity value observed in the posterior cortex may actually be caused by strong attenuation in the nucleus. It should be stressed that this is true of all in vivo observations of ocular opacity, whether made photometrically or by slit-lamp photography. In clinical use, however, where measurements are repeated on the same patient at suitable time intervals, the variation in opacity gives us a means of adequate assessment of changes in light scattering, and the above discussion would therefore seem to be of secondary importance.

The convergent nature of the slit-lamp beam results in variations in flux density, which is greater in the beam focus. In the present study the beam was focused at each location of measurement so as to avoid any variation in the image luminance due to the changes in flux density around the beam focus. This problem exists also in slit-lamp photography of the lens. Because of the above-mentioned problems the present study reports on the light scatter focused only in the anterior parts of the lens.

Since our method is based on the comparison of brightness, any color shift in the scattered light may interfere with accurate evaluation of brightness. We used the red-free filter of the Haag-Streit slip lamp because most of the scattering occurs in the shorter wavelengths and our eyes are highly sensitive in these regions of light.

The results obtained with our method corroborate previous results achieved by Goldmann, Wolf and Gardiner, Sigelman et al. The present study has demonstrated that our simple instrument provides a relatively accurate estimation of light scattering in the human lens. Its performance is equal to that given by much more sophisticated, expensive equipment. Although there are still many problems which await solution in regard to the exact determination of light scattering from the lens, we feel sure that the presently described instrument should encourage more clinical research on cataract formation and be an important aid to the ophthalmologist in clinical evaluation of the lens.

From the Department of Ophthalmology, Beilinson Medical Center, and Tel-Aviv University Sackler School of Medicine, Israel. Submitted for publication March 26, 1979. Reprint requests: I. Ben-Sira, Department of Ophthalmology, Beilinson Medical Center, Petah-Tiqva, Israel.

**Key words:** lens, light scattering, senile lens changes, cataract, clinical instrument

**REFERENCES**