Localization of Cortical Cataract in Subjects of Diverse Races and Latitude

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PURPOSE. To compare the characteristics of early cortical cataract localization in three groups in cataract epidemiologic surveys performed in Reykjavik, Melbourne, and Singapore.

METHODS. Individuals who had right eyes with an area of cortical opacity less than 20% of the pupil when dilated 7 mm or more were selected as subjects. This included 197 subjects from the Reykjavik Eye Study, 231 from the Vitamin E, Cataract, and Age-Related Maculopathy (VECAT) study in Melbourne, and 92 from the Singapore-Japan Cooperative Cataract Study, all showing early-stage cataract in pupils dilated to 7 mm or more. Scheimpflug and retroilluminated photographs were used to locate opacities. Localization of cortical cataract was determined by dividing the retroillumination image into seven concentric circles with diameters of 1 through 7 mm, and eight sections of 45° radial octants. The positive rate of opacification was then calculated for each quadrant.

RESULTS. The highest positive rate of opacification was observed in the lower nasal quadrant in all groups. The relative risk of the prevalence of cortical opacity in the lower nasal oblique hemisphere to the upper temporal oblique hemisphere was the highest in the Singaporean subjects followed by those of Melbourne and then of Reykjavik.

CONCLUSIONS. The prevalence of cortical cataract was higher in the lower nasal quadrant than in the other quadrants for all subjects of diverse race in three climatically different locations. This higher prevalence was most pronounced in subjects living at low latitude. These results support the view that solar UV exposure is a possible risk factor for development of human cortical cataract. (Invest Ophthalmol Vis Sci. 2003;44: 4210–4214) DOI:10.1167/iovs.01-1221

Several epidemiologic research reports have indicated an association between ultraviolet B radiation (UV-B) and cortical cataract.1-10 These studies assessed UV exposure by measuring ambient UV level or personal exposure. Some of the studies show the effect of UV-B on cortical opacity by its characteristic localization.11-14 The prevalence of cortical opacity in the lower nasal quadrant was highest in all the studies. These results affirmed the theory of Coroneo et al.15,16 that UV radiation from the very temporal edge of the cornea focuses on the nasal side of the limbus and lens. If the correlation between UV radiation and the localization of cortical opacity is significant, the characteristics of localization must differ among subjects dependent on UV exposure levels characterized by different races living at various latitudes. Asano et al.14 reported the localization of cortical opacity in subjects living in three different areas of Japan (Hokkaido, Noto, and Okinawa). According to their results, cortical opacity was present in all the quadrants in the subjects from Hokkaido, which is located in northern Japan and has the lowest UV level of the three locations, and was seen most frequently in the lower nasal quadrant in subjects from the other two locations.

In the present study, we investigated the characteristics of the localization of cortical opacity in the subjects of three epidemiologic studies performed in Reykjavik (Iceland), Melbourne (Australia), and Singapore. Using the annual mean,17 the UV level is 5.3 higher in Singapore and 3.2 times higher in Melbourne than in Reykjavik.

METHODS

The climatic environments of the survey areas are shown in Table 1. Erythemal UV in the three areas was obtained from data provided by the U.S. National Aeronautics and Space Administration Total Ozone Mapping Spectrometer (TOMS/NASA)17 and were converted into UV-B dose in accordance with the ratio of UV-B and erythemal UV reported in Japan.18

The Statistical Bureau of Iceland took a random sample of 1635 citizens of Reykjavik aged 50 years and more, by using the population census. The same proportion of subjects (6.4%) was selected for each year of birth and for both sexes. Of those 1635 individuals, 1379 were successfully contacted, and of these, 1045 elected to participate and were subsequently examined. Thus, the participation rate was 64.0% of the randomly selected total sample population, and the response rate was 75.8%. The Vitamin E, Cataract, and Age-Related Maculopathy (VECAT) study center was based in an inner suburb of Melbourne. Volunteers living within a 15-km radius of the study center were recruited to participate in a clinical trial, by using media advertisement, electoral roll mailings, and approaches to community group leaders and general practitioners. Of the 1906 volunteers who were screened by telephone, 1289 (67%) were subsequently examined at the study center, 85 (7%) were excluded before randomization, and

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1Deceased 1998.

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1204 (93%) were enrolled and randomized. The Singapore-Japan Cooperative Cataract (SJCC) Study was population based, although it did not use an ideal random sample. Long-term Singaporean residents of Chinese descent aged 50 years or more were surveyed. The invitation to participate was conveyed by the Singapore Action Group of Elders (SAGE), which has an island-wide communications network. Among 550 invitations, 517 (94.0%) subjects responded and were subsequently examined. Among the sample of individuals aged 50 years or more who joined the Reykjavik Eye Study,18 the VECAT study,19 and the SJCC Study,20 those with grade 1 cortical cataract, in which the area of cortical opacity in the right eye was less than 20% of the pupil dilated 7 mm or more, were enrolled in the present survey. All subjects gave informed consent to participate, and all procedures adhered to the provisions of the Declaration of Helsinki. Eyes with a cortical cataract of a grade higher than 1, or with a granular type of cortical opacification or a dilated pupil diameter less than 7 mm were excluded. This left 197 subjects (41.1% men) aged 50 to 85 years, (66.4 ± 8.7, mean ± SD) from the Reykjavik Eye Study, 231 subjects (55.2% men) aged 50 to 81 years (mean, 68.9 ± 6.8) from the VECAT study, and 92 subjects (43.5% men) aged 50 to 87 years (mean, 62.2 ± 7.2) from the SJCC Study who were selected for analysis. All the subjects from the Reykjavik Eye Study and the VECAT Study were white and 98% of the subjects from the SJCC Study were Chinese.

Cortical opacity was judged according to the Japanese Cooperative Cataract Epidemiologic Study Group (JCCESG) System.21 The pupils were dilated to the maximum with mydriatic drugs. In all the subjects, the area of cortical opacity was identified and measured using retroillumination images taken by the anterior eye segment analysis system (model EAS-1000; Nidek, Gamagori, Japan). The localization of cortical opacity was judged from photographed images. Each image was divided into 56 sections by seven concentric circles radiating from 1 to 7 mm and eight radial lines. The lens was thus divided into 56 sections by seven circular and eight radial sections. Calculations were made to establish how often each section was affected. The pupil's size was 7 mm or more.

The relative risk of development of cortical opacity in the lower nasal quadrant, rather than the upper temporal quadrant, was highest in Singapore and lowest in Reykjavik. In fact, the risk ratio of development of cortical opacity between the lower-nasal and upper-temporal quadrants in Singapore was 3.4 and 2.4 times higher than that in Reykjavik and Melbourne, respectively. Table 2 also shows the relative risk of opacities in the nasal versus temporal and upper versus lower hemispheres, as well as upper nasal versus upper temporal and lower temporal versus upper temporal quadrants, with 95% CIs.

**Table 1.** Annual Average Climatic Measures for Each Survey Location

<table>
<thead>
<tr>
<th>Location</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
<th>Rainfall (mm)</th>
<th>UV-B (kJ/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>0°, 17°N, 103°, 51°E</td>
<td>26.7</td>
<td>84</td>
<td>2172</td>
</tr>
<tr>
<td>Melbourne</td>
<td>57°, 46°S, 14°, 58°E</td>
<td>15.5</td>
<td>65</td>
<td>639</td>
</tr>
<tr>
<td>Reykjavik</td>
<td>64°, 48°N, 21°, 58°W</td>
<td>4.4</td>
<td>82</td>
<td>798</td>
</tr>
</tbody>
</table>

**RESULTS**

Figure 2 shows the distribution of cortical opacification within the seven different circles (1–7 mm diameter) and eight radial lines in the three locations. The octants between the radial lines (A–H) can be combined into quadrants A+D upper nasal, C+D lower nasal, E+F lower temporal, and G+H upper temporal. The most predominant area of opacification was the lower nasal quadrant in all three populations. Away from the lower nasal area, the prevalence decreased. The prevalence of opacification in the area between 6 and 7 mm diameter in all the quadrants was highest in the Icelanders and lowest in the Singaporeans.

**DISCUSSION**

This study shows that prevalence of the early stage of cortical opacity was highest in the lower nasal quadrant in subjects of three locations, each with different latitude and UV levels: Reykjavik, Melbourne, and Singapore. The prevalence of opacities in each hemisphere and each quadrant and the relative

![Image](https://via.placeholder.com/150)

**Figure 1.** The localization of cortical cataract was established using retroillumination digital images of the lens with concentric circles 0 to 7 mm and eight radial lines. The lens was thus divided into 56 sections by seven circular and eight radial sections. Calculations were made to establish how often each section was affected. The pupil’s size was 7 mm or more.
risk of opacification in each hemisphere and quadrant of the pupil differed among the three populations. The relative risks in the nasal versus temporal, lower-upper, upper-nasal-upper-temporal, lower-temporal-upper-temporal and lower-nasal-upper-temporal were the highest in the Singaporeans followed by the subjects in Melbourne and Reykjavik.

Although there are several studies that investigated the localization of cortical opacity, analysis of all the stages of cortical opacity was undertaken in most of the studies. The present study was restricted to the early stage of cortical cataract, because it is important to find out the part of the lens in which cortical opacity first develops. Sasaki et al. found a characteristic localization of cortical lens opacification at an early stage. At the advanced stage of cortical cataract, the opacity is usually seen in all the quadrants, and the originating localization is no longer evident. For the above reasons, we enrolled only subjects who had eyes with grade 1 cortical opacity covering less than 20% of the area seen on retroilluminated photographs through a pupil dilated to 7 mm or more. The prevalence of grade 1 cortical opacity in this study was higher in Reykjavik (Fig. 2A) than in Singapore (Fig. 2C); however, the prevalence of cortical opacity of grade 2 or more was higher in Singapore. The age- and sex-adjusted prevalence of grade 1 and grade 2 or more severe cortical opacities were 43.2% and 14.3% in Reykjavik and 25.1% and 45.9% in Singapore, respectively.

As in the previous studies, all the groups showed the highest prevalence of cortical opacification in the lower nasal quadrants. The prevalence of cortical opacity in the upper and
temporal hemispheres, however, was highest in the subjects of Reykjavík followed by Melbourne and then Singapore. These results may indicate that the onset of cortical opacities in Singaporeans is frequently located in the lower nasal but rarely in the upper or temporal quadrants, whereas in the Reykjavík subjects, the onset of opacification may be found in any quadrant, with some predominance in the lower nasal quadrant.

Using a mannequin model, Sakamoto et al.23,24 showed that exposure of the eye to UV light from the upper frontal direction is higher in the nasal than in the temporal portion, and this tendency is greater with exposure from the temporal direction. Because solar light mainly arrives from the upper direction, the main UV radiation impinges on the lower part of the lens. Because the zenith angle in Singapore is small, UV light exposure to the lower hemisphere is relatively high. On the contrary, because the zenith angle in Reykjavík is large, there is relatively increased radiation of the upper part of the lens. Using a mannequin model, Sakamoto et al.23,24 showed that exposure of the eye to UV light from the upper frontal direction is higher in the nasal than in the temporal portion, and this tendency is greater with exposure from the temporal direction. Because solar light mainly arrives from the upper direction, the main UV radiation impinges on the lower part of the lens. Because the zenith angle in Singapore is small, UV light exposure to the lower hemisphere is relatively high. On the contrary, because the zenith angle in Reykjavík is large, there is relatively increased radiation of the upper part of the lens. But the fact is that the ground in Reykjavík is very rarely covered with snow during the main months of UV radiation, and the reflectance is therefore not from snow but mostly from concrete buildings and asphalt roads, as is true in Singapore and Melbourne. On this point, we tried to estimate the solar radiation from each direction. Figures 4 and 5 show the monthly fluctuation of the averaged zenith angle at local noon and estimates of the annual amount of directional solar radiation reaching the three areas, respectively. Figure 5 shows that in Singapore, a large proportion of the solar radiation comes from a high direction, whereas in Reykjavík much of it comes from a low direction. Considering the angle of solar radiation in Figures 4 and 5, together with the prevalence of the location of cortical lens opacification shown in Figure 2, these data match well and indicate an effect of solar radiation on the formation and location of cortical opacities.

The differences attributed to latitude between Reykjavík and Singapore may also be attributable to differences between races. The dark brown iris common in Singapore is believed to absorb more sunlight than the light-colored iris common in Reykjavík. Cumming et al.25 reported that eyes with dark brown irises were more likely to have nuclear or posterior subcapsular cataract than eyes with lighter-colored irises; however, they found no difference in prevalence of cortical cataract between eyes with different iris colors. In the Reykjavík Eye Study we did not find a brown iris to be a risk factor for cortical cataract grade I, and it was found to be protective.

### Table 2. Positive Rate Ratio of Cortical Opacity for Hemispheres and Quadrants

<table>
<thead>
<tr>
<th>Hemispheres</th>
<th>95% CI</th>
<th>L/U 95% CI</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reykjavík</td>
<td>1.149</td>
<td>1.062–1.237</td>
<td>1.288</td>
</tr>
<tr>
<td>Melbourne</td>
<td>1.152</td>
<td>1.042–1.262</td>
<td>1.843</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quadrants</th>
<th>95% CI</th>
<th>LT/UT 95% CI</th>
<th>95% CI</th>
<th>LN/UT 95% CI</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reykjavík</td>
<td>1.038</td>
<td>0.855–1.222</td>
<td>1.337</td>
<td>1.177–1.496</td>
<td>1.529</td>
</tr>
<tr>
<td>Melbourne</td>
<td>0.867</td>
<td>0.589–1.144</td>
<td>1.707</td>
<td>1.488–1.926</td>
<td>2.173</td>
</tr>
<tr>
<td>Singapore</td>
<td>1.308</td>
<td>0.646–1.969</td>
<td>2.615</td>
<td>2.045–3.185</td>
<td>5.231</td>
</tr>
</tbody>
</table>

The data show relative risk and 95% CI. N, nasal; T, temporal; L, lower; U, upper; UT, upper temporal; UN, upper nasal; LT, lower temporal; LN, lower nasal.

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**Figure 4.** Monthly average of zenith angle at noon in Reykjavík, Melbourne, and Singapore.

**Figure 5.** Annual amount of UV radiation in each direction. Hourly UV radiation is summed up into the same zenith angle throughout the year. Unit: relative intensity of UV × hours.
against grade 2 or more severe cortical cataract. This implies that the influence of iris color difference between Singaporean Chinese and whites may be deemed insignificant to our results. It also appears that the eyes sit relatively deeper in the orbit of whites than in Chinese and that the eyebrow ridge is more prominent in whites, possibly leading to less difference in UV radiation exposure between the upper and lower halves of the lens than in the Chinese population of Singapore. The ocular UV exposure is also strongly affected by the degree of lid opening.

Although there are many risk factors for cortical opacity, our results suggest that UV exposure may play an important role in the development of cortical lens opacification. The relationship between individual UV exposure and localization of cortical opacity should be further investigated to confirm the results obtained in this study.

References