Lens Transmission of Blue–Green Light in Diabetic Patients as Measured by Autofluorophotometry

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Lens transmission for blue-green light (λ = 490 nm and 530 nm) was assessed by means of fluorophotometry in 67 diabetic patients without cataracts and compared with that of 52 healthy controls. Lens transmission was determined from peak autofluorescence values in the anterior and posterior parts of the lens, assuming an about equal fluorescence peak quantum efficiency in both parts. The variation in lens transmission between individuals of about the same age was found to be larger in the diabetic patients than in the healthy controls. Decrease in lens transmission as a function of age occurred about 15 years earlier in patients with diabetes of more than 10 years' duration than in the healthy controls. The calculated average extra decrease of lens transmission in the diabetic group amounted to 0.5% for each year of diabetes. Invest Ophthalmol Vis Sci 26:532–536, 1985

A cataract can be defined as an opacity of the crystalline lens localized in the anterior/posterior cortex and/or nucleus. Cataract formation is preceded by years of a gradual decrease of lens transmission due to increasing scattering and absorption of light in the lens.[1]

Little is known of senile cataract genesis. A possible cause of the opacification is the exposure to natural ultraviolet (uv) light in daily life that induces production of fluorescing agents in the lens. These fluorescing agents are responsible for the normal yellow discoloration of the lens nucleus, resulting in a gradual decrease in lens transparency to violet light with age.[2–6]

In diabetic patients, at least two types of cataract do occur: (1) the so-called "true diabetic cataract," which occurs mainly in poorly controlled insulin-dependent diabetic patients and which can be attributed to an effect of hyperglycemia on lens metabolism; and (2) the senile cataract, which occurs mainly in older patients and which cannot be distinguished from senile cataract in nondiabetic subjects. Some observers noticed a higher incidence of senile cataract in diabetic patients than in nondiabetic patients of comparable age,[7–10] while others did not.[11,12] However, it has been demonstrated that cataract extraction is carried out more frequently in diabetic patients than in nondiabetic patients[9,13,14] and that senile cataract may occur at a younger age[15] and develops faster than in nondiabetic patients.[16] The lens autofluorescence of diabetic patients (as measured in vivo) was found to increase with age more rapidly than that of healthy controls.[17–19]

In this study, lens transmission for blue-green light was determined as a function of age in diabetic patients without cataract. The transmission was calculated from the ratio between peak autofluorescence values in posterior and anterior parts of the lens according to a method described previously;[20] the autofluorescence was measured by means of fluorophotometry along the optical axis of the lens.

Materials and Methods

Lens transmission for blue-green light of 41 male and 26 female diabetic patients (type I) without cataract was assessed. The patients were recruited from the Diabetes Out-patient Department or from the Department of Internal Medicine of the Academic Hospital of Leiden. Their ages varied from 18 to 84 years, and the duration of the diabetes (time between diagnosis and assessment) ranged from 6 months to 48 years. Informed consent was obtained after the nature of the procedure had been explained fully. Pregnant women were excluded from the study. The results of lens transmission measurement of diabetic patients were compared with those of 30 male and 20 female healthy volunteers without cataracts, aged between 10 and 92 years.[20]

Autofluorescence of the lens was measured with a computer fluorophotometer (Fluorotron Master of Coherent Radiation Inc.), fitted with a special lens

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("anterior segment adaptor") for detailed scanning of lens, anterior chamber, and cornea. Contact lens or fluorescein was not required. Mydriatics were not given, as it was not necessary to dilate the pupil. Moreover, the focusing of the apparatus appeared to be less accurate in mydriasis.

The green part of the autofluorescence spectrum of the lens, excited by a beam of continuous blue light, was scanned along the optical axis of the eye by moving the internal lens system of the fluorophotometer in instrumental steps of 0.1 mm by a computer-controlled motor. The wavelengths of exciting and fluorescent light were set by the instrument's fixed color filters with fairly broad bands, with peaks at 490 nm and 530 nm, respectively. The measured autofluorescence as a function of the distance in the eye was recorded on magnetic disc and plotted on paper.

The assessment of lens transmission is described extensively elsewhere[20] and is derived from a principle suggested by Zeimer.[19] The assessment is based on the assumption that the maximum quantum efficiency for autofluorescence is about equal in the anterior and posterior part of the lens. Consequently, any difference in fluorescence intensity between both parts can be attributed to a loss of (blue) exciting and fluorescent (green) light in the lens by scatter and by absorption in the nucleus and cortex. The lens transmission for blue–green light, T, then can be approximated by the equation

$$T = (F_P/F_A)^{1/2} \quad (1)$$

where F_A and F_P are the values of the relative peak autofluorescence in the anterior and posterior part of the lens, respectively. From this equation, it follows that a certain transmission value can occur with a high as well as with a low average peak autofluorescence value.

The validity of the assumption concerning an equal peak fluorescence quantum efficiency in the anterior and posterior part of the lens was sustained by in vitro measurements of peak fluorescence efficiency in both parts of donor lenses.[20,21]

The average ratio between posterior and anterior peak amounted to 0.93 ± 0.07 SD[20] and 0.85 ± 0.23 SD,[21] resulting in an average error in the calculation of lens transmission of −3.6% and −7.8%, respectively.

Although the light path of exciting and measured fluorescence light is considered to be along the optical axis, they are actually about 20 deg off. As a result, the amount of light absorbed may vary to some extent with the diameter of the pigmented zone. Therefore, our measurements were restricted to lenses considered with the naked eye to be transparent or diffusely opalescent.

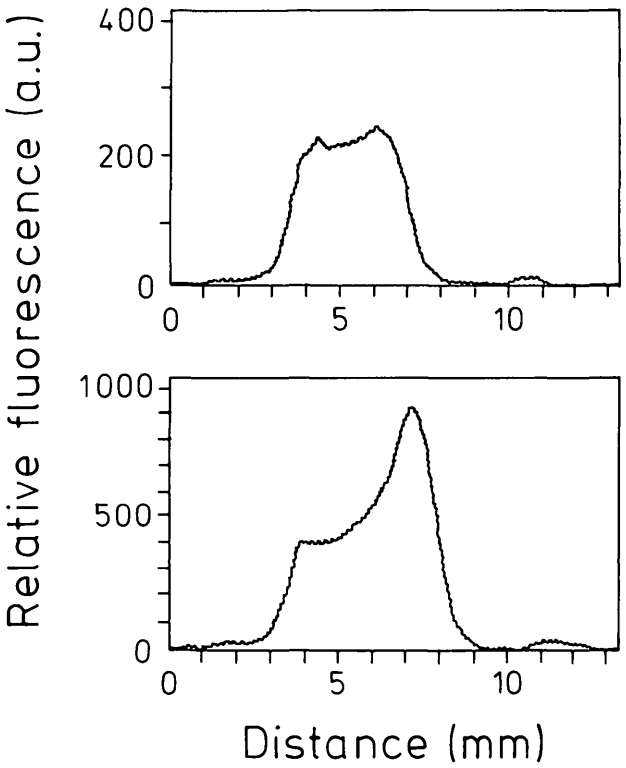

Fig. 1. Relative autofluorescence of the right lens in two male diabetic patients aged 46 years. *Upper panel,* duration of diabetes: 7 years; calculated lens transmission (equation [1]): 0.98. *Lower panel,* duration of diabetes: 42 years; calculated lens transmission (equation [1]): 0.67.

The average value of lens transmission was calculated from three measurements for each eye.

Results

Autofluorescence of the Lens

Autofluorescence as a function of distance in the anterior segment of the eye of two diabetic patients, aged 46 years, is presented in Figure 1. One patient with a diabetes of only 5 years' duration shows a rather symmetric curve (Fig. 1, upper panel), whereas the other one with a diabetes duration of 42 years shows an asymmetric curve (Fig. 1, lower panel); the fact that the posterior fluorescence value is lower than the anterior value is ascribed to a loss of exciting and fluorescent light in the lens.

Lens Transmission versus Age

In order to differentiate according to the duration of diabetes, the patients were divided into two groups, with a duration of diabetes of up to and more than 10 years. The lens transmission as a function of age is presented for both groups in figures 2 and 3, respectively.

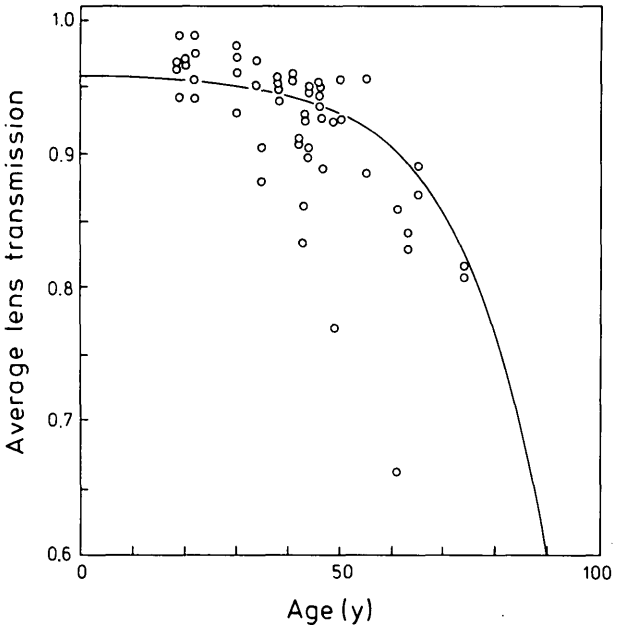

Fig. 2. Average lens transmission as a function of age for patients suffering from diabetes for 10 years' duration or less. The solid line corresponds with a least-squares approximation to the data points of healthy controls.

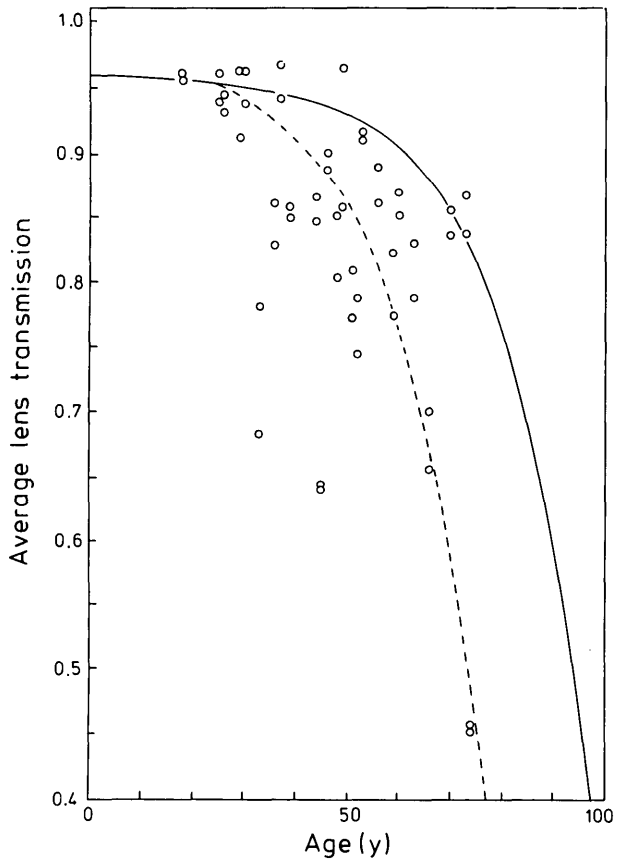

Fig. 3. Average lens transmission as a function of age for patients suffering from diabetes for more than 10 years' duration. Solid line: corresponds with a least-squares approximation to the data points of healthy controls. Broken line: least-squares approximation to the data points in the figure.

Table 1. Values of parameters in equation (2) for healthy controls and diabetic patients as determined by computer approximation

	T_o	t_o (y)	t_m (y)	RD (%)
Healthy controls	0.960	105.9	16.13	8.2
Diabetic patients (duration > 10 years)	0.978	91.3	20.13	14.5

RD is the root mean square value of the relative deviation (expressed in percent).

The average lens transmission of healthy controls was determined previously by using the same method[20] and is given for comparison as a solid line in figures 2 and 3. The solid line represents the transmission T as a function of age t in years:

$$T(t) = T_o \cdot [1 - \exp((t - t_o)/t_m)] \quad (2)$$

The values of the parameters T_o, t_o, and t_m were calculated with the use of a computer program based on a "chi-square grid search" procedure,[22] which minimizes the average relative deviation between data points and function. The program was developed and run on the fluorophotometer computer; the calculated parameter values are presented in Table 1.

The broken line in Figure 3 was determined with the same computer program applied to the data points in the figure. The corresponding parameters also are given in Table 1. From Figures 2 and 3, it can be concluded that lens transmission of diabetic patients decreases with increasing age in an analogous way to that of the healthy controls. The relative deviation in the diabetic group is larger than that in the healthy control group, suggesting a greater spread in transmission values of individuals of about the same age in the diabetic group (Table 1). The sharp decrease of lens transmission seems to occur on the average at a lower age in patients suffering from diabetes for 10 years or more than in the healthy controls (Fig. 3). This difference could be estimated from the difference in the values of t_o in equation (2) and amounted to about 15 years (Table 1).

Lens Transmission versus Diabetes Duration

To assess the effect of the duration of diabetes on lens transmission, the lens transmission values of diabetic patients had to be compared with the values of healthy controls. Therefore, a correction was performed by dividing the lens transmission value of diabetic patients by that of healthy controls of the same age, as calculated from equation (2). The values

of lens transmission thus corrected are presented as a function of the diabetes duration in Figure 4.

Notwithstanding the large spread in the data points, the extra decrease in lens transmission as a function of diabetes duration is obvious. The broken line in Figure 4 was obtained by a linear regression procedure applied to the data points and represents the function $\Delta T(t)$:

$$\Delta T(t) = A + B \cdot t \qquad (3)$$

with t = diabetes duration in years, A = 1.007 ± 0.012 (estimated error), and B = 0.00467 ± 0.00066 (estimated error). The function corresponds with an average extra decrease in lens transmission of about 0.5% per year of diabetes in comparison with the healthy controls.

Left Eye versus Right Eye

In order to compare the lens transmission of the left eye with that of the right eye, the ratio between both transmission values was calculated for each diabetic patient. The average value of the ratios amounted to 0.995 ± 0.060 SD, which is indicative

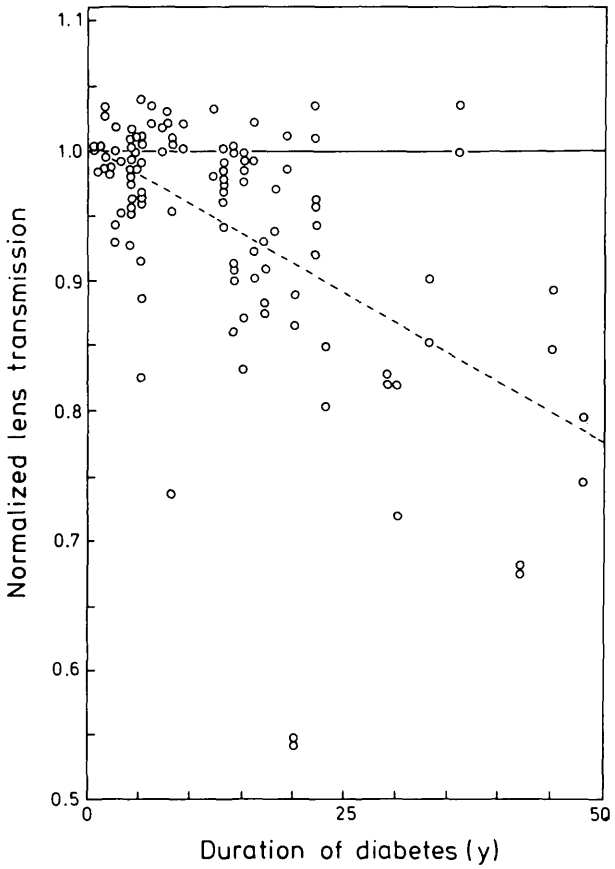

Fig. 4. Normalized lens transmission versus duration of diabetes: The transmission values were corrected for the normal decrease of lens transmission as a function of age. Solid line: average value for normals. Broken line: linear regression to the data points.

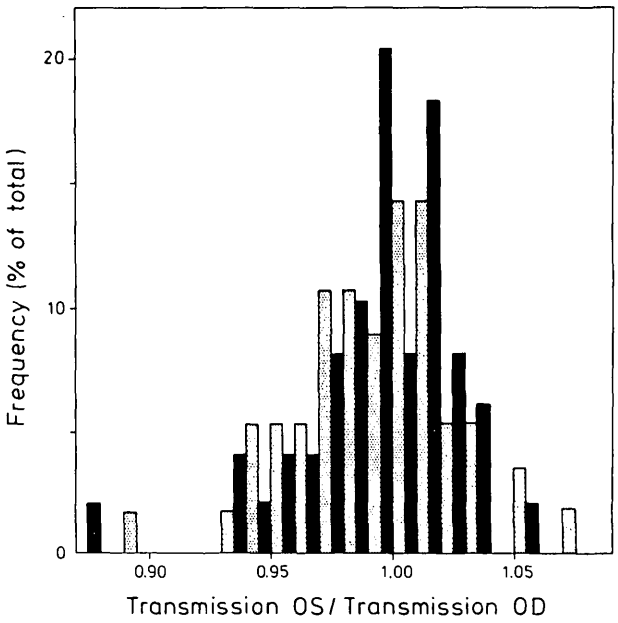

Fig. 5. Left/right transmission ratio histogram. Solid bars: healthy controls. Hatched bars: diabetic patients.

of an about simultaneous decrease in lens transmission in both eyes. The average value for the healthy controls amounted to 0.996 ± 0.042 SD[20]; the standard deviation being about 50% larger in diabetic patients in comparison with that in healthy controls implies a higher probability for a difference in lens transmission between both eyes.

The distribution of the ratios, expressed in percentage of the total number of persons is presented for the diabetic patients and for the healthy controls in Figure 5. The shape of both histograms is rather symmetric, indicating no left/right preference in case of differences in lens transmission between both eyes.

Discussion

Lens transmission measurements for blue–green light were performed in vivo in patients suffering from diabetes mellitus and compared with similar measurements in healthy controls. The transmission values were calculated from the ratio between peak autofluorescence values in the anterior and in the posterior part of the lens as measured by fluorophotometry. The measurements were performed in a few minutes without manipulation of the eye (no contact lens) and without the use of drugs (fluorescein, eye drops, etc).

There were several findings indicating an influence of diabetes on lens transmission: (1) the variation in lens transmission values between individuals of about the same age was larger in diabetic patients than in the healthy controls; (2) in patients with diabetes for more than 10 years, the sharp decrease in lens

transmission as a function of age occurred 15 years earlier than in the healthy controls; (3) the extra decrease of lens transmission value that can be attributed to the diabetes amounted to about 0.5% for year year of diabetes.

The study suggests that not only cataract but also the prestage of diffuse opacification of the lens develops at an earlier age in diabetic patients than in healthy controls.

Lens transmission values of healthy controls as measured with the described method show a sharp decrease, starting at the age of about 50 years. However, with the use of Scheimpflug photography with white and UVA light, such a decrease in blue green light transmission was found to occur between birth and adolescence.[2] This discrepancy in time of onset possibly may be attributed to the different mode of fluorescence measurement (at a larger angle to the light path), to the postmortem period of several hours before measurement, and to manipulation of the eye during lens extraction; furthermore, our results apply to the region situated between the posterior and anterior fluorescence peak of the lens, thus excluding lens capsule and surface layer.

The objectivity of the method and its reproducibility[20] make it specially suitable for follow-up of individual patients. The method may be less usable for comparing groups of patients because of the large spread in individual transmission values.[17]

Key words: lens, transmission, diabetes, fluorescence, fluorophotometry, cataract

Acknowledgments

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