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Anterior lens curvature

Comparisons between normal eyes and those with primary angle-closure glaucoma

RONALD F. LOWE

From the Glaucoma Unit, the Royal Victorian Eye and Ear Hospital, and the Ophthalmic Research Institute of Australia

A pupil-block angle-closure glaucoma hypothesis was submitted by Curran (1920, 1931), who observed that after iridectomy for acute glaucoma the iris hugged the lens much more closely and extensively than after iridectomy before cataract extraction.

Rosengren (1931) showed the association between shallow anterior chambers and acute congestive glaucoma. Following the gonioscopic investigations by Barkan (1938, 1954) and Sugar (1941) and the teachings of Chandler (1952), Curran's hypothesis became established and pupil-block angle-closure glaucoma became defined as a distinct disease. Various authors proposed mechanical explanations for the pupil block (Sugar 1964; Lowe, 1966a; Mapstone, 1968; Wyatt and Ghosh, 1970).

During the examination of a large series of eyes that had pupils dilated after peripheral iridectomy for the treatment or prophylaxis of primary angle-closure glaucoma, I was struck by the marked curvature of the anterior lens surface within the enlarged pupil. The lens frequently appeared as though it were herniating through the enlarged pupil with the pupil margin of the iris seeming to grip the lens. Investigations were therefore pursued to measure the anterior lens curvatures of a series of such eyes for comparison with a series of normal eyes from subjects of similar age.

Subjects

Examinations were conducted on 93 eyes of 48 patients (31 women; 17 men) who had had various types of primary angle-closure glaucoma (Lowe, 1966b). Of these patients, 31 had been treated for acute primary angle-closure glaucoma, ten for attacks limited to intermittent angle-closure glaucoma, and seven for progressive angle-closure glaucoma. Fifty eyes were involved by the glaucoma and 43 were fellow eyes. Eyes with apparent damage to the lens by the glaucoma or by surgery were excluded from the investigation. Peripheral iridectomy had been performed on 69, iridencleisis on fourteen, and Scheie's sclerocautery on eight; two had had no surgery. All surgery had been completed at least one month before the examinations, by which time no treatment was being administered.

The control series comprised 46 persons with normal eyes from the Hospital's outpatient department; there were 33 females and thirteen males with an age range of 23 to 77 years. Most had attended for headaches or presbyopia and the special tests were performed while the pupils were bilated with 2 per cent. homatropine and cocaine eyedrops. None was accepted if any eye disease was present, except that some of the most elderly showed minor lens opacities or macular degeneration in keeping with their age.

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Methods

The radius of corneal curvature was measured in the vertical and horizontal meridians with a Haag-Streit keratometer, and the anterior chamber depth by Haag-Streit pachometers (Lowe, 1966c); time-amplitude ultrasonography, with a Siemen's 15 MHz. echo-ophthalmograph, was used to determine axial length, anterior chamber depth, lens thickness, and lens position (Lowe, 1967); narrow-beam vertical-slit photographs were taken with a Zeiss photoflash slit-lamp, using very narrow apertures with the slit-beam centres and normal to the cornea and with the binocular microscope and camera set at a constant angle of 45° on the right-hand side of the lamp arm.

Negatives were obtained on 35 mm. Kodak Tri-X film; positives were printed at 10 × enlargement on Agfa Syntobrom (minimum shrink) paper which was dried naturally in air. Anterior and posterior corneal curves and anterior lens curves were matched against arcs etched on clear plastic. The best circular fit was read for the central optical zones of the cornea and lens to give the respective "photographic" radii of curvature. The photographic distance from the anterior corneal surface to the anterior lens surface was measured by a vernier caliper.

Readings and photographs were taken four times and the means were used in the calculations. Both eyes were treated separately and included.

Using the known anterior corneal radius of curvature (keratometer), the known distance from the anterior corneal surface to the anterior lens surface (pachometer and ultrasonography), and measurements from the photographs, skew ray tracing by computer permitted calculation of anterior lens curvature.

Results

COMPARISONS OF ANTERIOR LENS CURVATURE

The means of the radii of curvature in the vertical meridian of the anterior lens curvature for the normal eyes and those with primary angle-closure glaucoma are shown in Table I. The result for normal eyes (10·29 mm. ± 1·78) is very similar to that generally quoted in the ophthalmic literature (10 mm.). The mean radius of anterior lens curvature of the eyes with primary angle-closure glaucoma was 7·96 mm. ± 0·99, and the variance ratio showed an extremely significant difference between the two series.

Table I *Comparison of radius of curvature of vertical meridian of anterior lens surfaces of normal eyes and eyes with primary angle-closure glaucoma*

Series of eyes	*Normal*	*Angle-closure glaucoma*
No. of eyes	92	93
Mean radius (mm.)	10·29	7·96
Standard deviation	1·78	0·99
S.E. of mean	0·185	0·104
Range (mm.)	7·50–15·38	6·17–11·04
Variance ratio	$F = 3·2$	
Significance	$P \ll 0·001$; extremely significant differences in variances	

CORRELATIONS OF ANTERIOR LENS CURVATURE AND ANTERIOR CHAMBER DEPTH

Radius of anterior lens curvature was compared with anterior chamber depth in each eye (Table II). An extremely significant correlation was found for both series of eyes (Figure).

Table II *Statistics of anterior lens curvature* (X) v. *ultrasonic true anterior chamber depth* (Y) *of normal eyes and eyes with primary angle-closure glaucoma*

Series of eyes	*Normal*	*Angle-closure glaucoma*
No. of eyes	92	91
Regression line	$Y = 1{\cdot}15 + 0{\cdot}15\,X$	$Y = 0{\cdot}41 + 0{\cdot}18\,X$
Correlation coefficient (r)	0·7221	0·6404
Significance	$P \ll 0{\cdot}001$ extreme	$P \ll 0{\cdot}001$ extreme

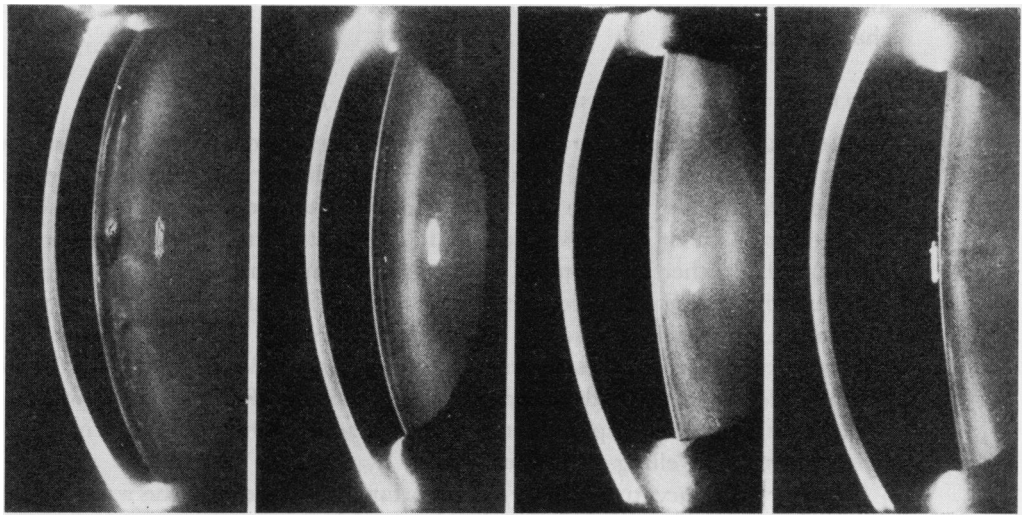

FIGURE *Slit-lamp photographs of a series of eyes, showing correlation between anterior chamber depth and curvature of anterior lens surface*

Discussion

ANTERIOR LENS CURVATURE

Normal eyes

Duke-Elder and Wybar (1961) quoted the radius of anterior lens curvature given by five authors, but only one (von Helmholtz) gave a range (8·8–11·9 mm.). Many other authors express the anterior lens curvature as refractive power and not as mm. of radius. The range of the radius of anterior lens curvature found seems surprisingly large (7·50–15·38 mm.), especially when compared with the radius of corneal curvature measured in the same vertical meridian in the same series of eyes (7·22–8·12 mm., mean $7{\cdot}65 \pm 0{\cdot}27$). However, the change in refractive index from anterior to posterior at the anterior lens surface is very small compared with that from anterior to posterior at the anterior corneal surface. If, as believed, the lens forms part of a coordinated optical

system favouring emmetropia, the large range of curvature of anterior lens surfaces becomes readily understood.

Eyes with primary angle-closure glaucoma

The mean anterior lens curvature in the vertical meridian for the eyes with primary angle-closure glaucoma was 2·3 mm. steeper than that in the same meridian for normal eyes. Statistically the difference was extremely significant. However, there was considerable overlap between the two series. These findings are comparable with the differences in the means, and overlap in the range, for other parameters for normal eyes and those that have had primary angle-closure glaucoma (Lowe, 1970a).

The standard deviation for the eyes that have had angle-closure glaucoma is considerably narrower (0·99 mm.) than that for the normal eyes (1·78 mm.). A possible reason is that the eyes that had angle-closure glaucoma were selected from the normal population by the pupil-block mechanism, and that the anterior lens surfaces were involved both directly and indirectly in the pupil block which acts only within a restricted range of anterior chamber anatomy.

CORRELATIONS WITH ANTERIOR CHAMBER DEPTH

Statistics show extreme correlation between anterior chamber depth and anterior lens curvature in both series of eyes—eyes with shallower anterior chambers have steeper anterior lens curves; those with deeper anterior chambers have flatter lens curves.

Anterior chamber depth is fundamentally a part of the compound optical system of the eye, and like other components its magnitude appears to be determined basically by polygenic inheritance. If corrections for age are introduced into statistics of its distribution in the general population, a binomial curve results (Rosengren, 1931). Without the age corrections, a skewness towards shallowness would be expected, because anterior chamber depth decreases during adult life on account of continued growth of the lens and a slight anterior lens displacement (Lowe, 1970b). Other changes in depth caused by lens sclerosis or swelling also occur.

Anterior lens curvature is also an important component of the refractive system of the eye and can also be expected to be determined by polygenic inheritance. Similarly, it is affected by the changes that occur in the lens with advancing age.

In the present statistics, adjustments for age have not been added to the anterior chamber depths or to the anterior lens curvatures, yet the measurements show extremely significant correlations. This indicates the persistence of the genetic determinants despite the changes that occur during life.

LENS CURVATURE AND PUPIL BLOCK

Anterior lens curvature has received almost no consideration as part of the mechanics of pupil block, although Mapstone (1968) explained a greater pupil-blocking force with the increased lens curvature of accommodation in order to account for the reading provocative test of Higgitt and Smith (1955).

The term "pupil block" is a convenient abbreviation for complex mechanisms that involve a wider area of iris–lens contact than just the pupil margin. Theories still need considerable development, although there is no doubt that the forward position of the anterior lens surface is of major importance. The need to consider anterior lens curvature is shown by an apparent grip by the pupil margin against the steeply curved lens when the

pupils are dilated after peripheral iridectomy. Whether pupil dilatation features in the early stages of primary angle-closure glaucoma is not known, but the increased intraocular pressure of an attack quickly causes pupil dilatation from sphincter paresis and from then on the steep anterior lens curvature may assume increasing importance.

Anterior lens curvatures can now be given definite values that can be used in calculations or incorporated in models.

Summary

The mean curvature of the anterior lens surfaces of eyes that have had primary angle-closure glaucoma is considerably steeper than the mean for eyes from the general population. The curvature of the anterior lens surface is correlated with the anterior chamber depth.

Curvature of the anterior lens surface needs consideration in relation to the pupil block that underlies primary angle-closure glaucoma.

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