Original Article

Axial Length: A Risk Factor for Cataractogenesis

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Abstract

Introduction: To evaluate whether eyes with longer axial lengths are associated more often with clinically significant cataracts than eyes with shorter axial lengths. Material and Methods: Charts of consecutive patients who underwent cataract surgery by 4 resident surgeons at Los Angeles County Hospital from July 2001 through May 2002 were retrospectively reviewed. Those patients whose axial lengths were significantly different between the 2 eyes (≥0.30 mm) and who had no pathology (other than cataracts) affecting visual acuity were included in the study. The 2 eyes in each patient were compared for preoperative best-corrected visual acuity and severity of cataracts. Results: Thirty-four of 353 patients had interocular axial length differences of at least 0.3 mm and were included in this study. Thirty-one patients had worse, 1 had equal, and 2 had better preoperative vision in the eye with longer versus the shorter axial length. Fourteen patients had more severe, 11 had the same, and 1 had less severe posterior subcapsular cataract (PSC) in the eye with longer axial length. In 8 patients, PSC severity could not be assessed due to obscuring nuclear sclerosis. Twenty-four patients had more severe, 7 patients had equal, and 3 patients had less severe nuclear sclerosis in the longer eye. Overall, longer axial lengths correlated with worse visual acuity, posterior subcapsular cataracts, and nuclear sclerosis. Diabetic status did not affect the correlation. The correlations were stronger with greater axial length asymmetry. Conclusions: Eyes with longer axial lengths have a higher prevalence of cataracts.

Ann Acad Med Singapore 2006;35:416-9

Key words: Axial myopia, Cataract formation

Introduction

There are several known risk factors for cataract formation, including older age, lower educational status, smoking, ultraviolet light exposure, trauma, dehydration, diabetes, uveitis and glaucoma.[1] Epidemiological research has been confounded by co-existing risk factors that are difficult to measure. An additional hurdle arises from the fact that different types of cataracts may have different aetiologies and risk factors. There is also no universally accepted method of quantifying the severity of cataracts for comparison across different patients, although some scales have been used in randomised clinical trials.[2]

High myopia is thought to be a risk factor for the development of cataracts.[3] However, several studies have had contradictory conclusions about whether lesser degree of myopia also predisposes to cataractogenesis.[4-7] Myopic shift can result from cataracts, particularly nuclear sclerosis. In addition, visual deprivation may lead to axial elongation in eyes with growth plasticity.[8] It is also not clear which cause of myopia (corneal steepness, lenticular changes, or long axial length) predisposes to cataract formation. In this study, we evaluate the relationship between axial length and the presence of cataracts by comparing the 2 eyes of a single patient.

Materials and Methods

The charts of consecutive patients evaluated by 4 resident physicians for cataract extraction at Los Angeles County Hospital (LACH) between July 2001 and May 2002 were retrospectively reviewed. Patients whose eyes had axial length differences ≥0.3 mm were included in the study. Patients with conditions that may predispose to asymmetric cataract formation, such as a history of trauma, glaucoma, uveitis, prior intraocular surgery, local steroid use, retinal detachment and congenital abnormalities, were excluded. Patients with other ocular diseases (any corneal, macular, vitreous, or optic nerve abnormalities) that could potentially affect visual acuity were also excluded. Diabetic patients,

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which constitute a significant proportion of the patient population at the clinic, were not excluded if they did not show evidence of macular pathology on clinical examination.

Axial length measurements (applanation A-scan, Mentor Advent A/B System, Norwell, MA), keratometry (Marco keratometer, Jacksonville, FL), and grading of cataract severity had been performed as part of the preoperative evaluation by each surgeon, prior to the initiation of this study. Visual acuity was measured on a standard Snellen chart in a darkened examination room. Manifest refraction and the best-corrected visual acuity (BCVA) of each eye were recorded. A difference of at least 1 line on the Snellen chart between the BCVAs of the 2 eyes is considered significant. Only eyes with BCVA 20/50 or worse were further evaluated for cataract surgery, in accordance with the general guidelines of the LACH Resident Eye Clinic.

Density of posterior subcapsular (PSC) changes and nuclear sclerosis were graded as trace, 1+, 2+, 3+ or 4+ (with no view of the posterior pole) by each resident surgeon according to his or her standard of practice. The types of cataract extraction procedure and intraocular lens implant selected were left to the discretion of the surgeon and attending physicians.

Postoperative refraction and BCVA were recorded when the eyes were deemed by the surgeon to have fully recovered from surgery, generally 2 to 3 months after surgery. In cases where the postoperative refractive error differed from the planned refractive error, the axial length and keratometry readings were re-checked.

Patients were stratified according to the degree of axial length asymmetry. Groups 1, 2 and 3 had a difference of 0.30 to 0.49 mm, 0.50 to 0.99 mm, and at least 1.0 mm, respectively. Axial length measurements were correlated with the BCVA and the density of PSC cataracts and nuclear sclerosis. The signed rank sum *P* values were obtained for statistical analyses.

Results

The 4 surgeons performed cataract surgeries on a total of 353 patients during the period of 11 months, of which 34 (9.6%) satisfied the inclusion criteria for this study. The mean age was 61 ± 12 years.

Table 1 and 2 summarise the findings. The longer eyes had worse BCVA, more severe PSC and more severe nuclear sclerosis among both diabetic and non-diabetic patients. These correlations were stronger among patients with greater axial length asymmetry. Because of the severity of nuclear sclerosis, the severity or presence of posterior subcapsular cataractous change could not be assessed in 8 patients.

Groups 1, 2 and 3 had median postoperative BCVA of 20/25, 20/30, and 20/50, respectively. Postoperative refraction did not result in any of the patients requiring repeat axial length or keratometry measurements (data not shown).

Table 1. Best-corrected Snellen Visual Acuity in the Longer Eye Relative to the Shorter Eye

	Better (at least one line)	Same	Worse (at least one line)	*P* value*
All patients (n = 34)	2	1	31	<0.001
Group 1 (n = 18)	2	1	15	0.002
Group 2 (n = 9)	0	0	9	0.004
Group 3 (n = 7)	0	0	7	0.02
Non-diabetic patients (n = 24)	1	1	22	<0.001
Diabetic patients (n = 10)	1	0	9	0.02

* Signed rank sum *P* value

Table 2. Severity of Cataracts in the Longer Eye Relative to the Shorter Eye

	Less severe	Equal	More severe	Cannot be determined	*P* value*
All patients (n = 34)					
Grade of PSC	1	11	14	8	0.001
Grade of NSC	3	7	24	0	<0.001
Group 1 (n = 18)					
Grade of PSC	1	5	6	6	0.13
Grade of NSC	3	2	13	0	0.02
Group 2 (n = 9)					
Grade of PSC	0	3	6	0	0.03
Grade of NSC	0	4	5	0	0.06
Group 3 (n = 7)					
Grade of PSC	0	3	2	2	0.50
Grade of NSC	0	1	6	0	0.03
Non-diabetic patients (n = 24)					
Grade of PSC	0	9	10	5	0.002
Grade of NSC	2	4	18	0	<0.001
Diabetic patients (n = 10)					
Grade of PSC	1	2	4	3	0.38
Grade of NSC	1	3	6	0	0.13

NSC: nuclear sclerotic cataract; PSC: posterior subcapsular cataract
* Signed rank sum *P* value

Discussion

Few studies have focused on the relationship between myopia and adult-onset cataracts. Most epidemiological investigations identify myopia as a risk factor in multivariate analysis.[5,6,7,9] Other studies associate cataracts (especially nuclear sclerosis) and myopia,[10-12] but do not distinguish whether myopia is the cause or the result of cataracts. In one study, high myopia was found to be

associated with cortical cataracts, nuclear sclerosis and PSC.[7] Axial length has been shown to be inversely associated with age at the time of cataract surgery.[13]

Among patients whose refractions were known 4 years previously, myopic changes appear to be the result, rather than the cause, of nuclear sclerosis.[4] Interestingly, in one study, myopic patients who had worn glasses for more than 20 years had a lower risk of cataracts.[14] The authors hypothesised that this was related to reduced ultraviolet light exposure as a result of the glasses. The present study suggests that longer axial length, not myopia per se, is an important predictor. Among the 5 patients who were hyperopic preoperatively in the longer eye, 4 developed cataracts in the longer eye first (data not shown).

In a report of 7 patients with severe axial length asymmetry, the longer eye (average axial length 28.07 mm, versus 22.98 mm in the other eye) harboured the more mature cataract.[15] After successful surgery, the longer eyes were all found to be amblyopic. Our study demonstrates that the relationship between longer axial length and cataract formation exists even among patients with lower degrees of asymmetry. Most patients in the current study also obtained good (better than 20/50) visual acuity after surgery. However, as expected, the greater the asymmetry, the more likely it was for the longer eye to have worse postoperative BCVA. However, the presence of amblyopia was not routinely evaluated preoperatively or postoperatively by the surgeons in this study.

Visual deprivation causes axial elongation, but this is generally thought to occur at a relatively young age, when the eye still has growth plasticity.[8,16,17] Five patients who underwent surgical evaluations for cataracts in the longer eye were found to have macular disease (RPE atrophy and chorioretinal changes in the macula) in the same eye. They were excluded from the study because it is not certain whether the axial length asymmetry was secondary to visual deprivation. It is likely that these changes represent myopic degeneration rather than primary macular disease. These findings are similar to those in previous case reports.[15] It is unlikely that an adult-onset cataract can cause an increase in axial length.

One potential confounding factor in this retrospective study is that the surgeons were not blinded to the patients' visual acuities when grading the cataracts. Visual acuity was checked prior to slit lamp examination. While the grading system may be slightly different among different surgeons, it should not affect the outcome of this study as long as each surgeon was consistent when comparing the 2 eyes of a single patient.

The mechanism of cataractogenesis in myopic eyes is not well understood. One hypothesis is that the reduced accommodative need of a myopic eye increases lens stress from the ciliary processes and separation of the peripheral lens fibres.[18,19] However, this model would not explain the current findings because the tension applied on the lens by the ciliary processes on the 2 eyes of the same patient would presumably be similar if the only difference was the axial length. It is possible that long axial length contributes to other subtle differences in the lens.

Lipid peroxidation by the retina may play an important role in cataract formation as well.[20] Increased oxidative stress on the retina depletes the reductive potential of the eye, leaving the lens more vulnerable to oxidative damage. Malondialdehyde (MDA), a product of lipid peroxidation, is found in higher concentration in the lens[21] and the vitreous[20] of myopic patients compared to those with age-related cataracts. Myopic cataracts also have a lower content of glutathione, an important reducing agent in the eye, and a higher concentration of oxidised glutathione.[20] Syneretic vitreous in the myopic eye may facilitate diffusion of oxidising molecules from the retina to the lens.[20] Alternatively, a biochemical change in the vitreous alone may potentiate cataractogenesis. Several studies[22-25] suggest a possible role of vitreoretinal degeneration in cataract formation. A higher incidence of cataracts among patients with vitreoretinal degenerative diseases such as gyrate atrophy, retinitis pigmentosa, Stickler's syndrome and Leber's congenital amaurosis supports this hypothesis.

The area covered by the retina is proportional to the square of the axial length (the relationship between the radius and the surface area of a sphere). Therefore, a 5% increase in axial length would lead to an 11% increase in retinal surface area. Myopia, in particular axial myopia, is associated with a thinning of the choroid and retina. It has been suggested that the rod outer segment of the myopic eye, which is rich in polyunsaturated fatty acids, is the site of increased lipid peroxidation secondary to chronic hypoxia from choroidal thinness and photic injury.[20] Alternatively, the altered retinal pigment epithelium may be responsible. In a chick model of sensory deprivation causing axial myopia, the rod outer segments were observed to be thicker and more elongated.[26] Myopia of pure corneal or lenticular origin is not known to be associated with such changes.

In summary, axial myopia is associated with the presence of cataracts. While the present study eliminates many potential confounding factors contributing to cataract formation, this relationship should be further studied in a prospective manner.

Acknowledgements

The authors wish to express their appreciation to Peter Pham, MD, Howard Ying, MD, PhD, and Kristina Tarczy-Hornoch, MD, DPhil for their contribution in data collection for this study, as well as Mrs Laurie Labree for her input on statistical analyses.

REFERENCES

1. West SK, Valmadrid CT. Epidemiology of risk factors for age-related cataract. Surv Ophthalmol 1995;39:323-34.
2. The Age-Related Eye Disease Study Research Group. The age-related eye disease study (AREDS) system for classifying cataracts from photographs: AREDS report no. 4. Am J Ophthalmol 2001;131:167-75.
3. Duke-Elder S. System of Ophthalmology. London: Kimpton, 1970;11:225.
4. Brown NA, Hill AR. Cataract: the relation between myopia and cataract morphology. Br J Ophthalmol 1987;71:405-14.
5. Ughade SN, Zodpey SP, Khanolkar VA. Risk factors for cataract: a case control study. Indian J Ophthalmol 1998;46:221-7.
6. Leske MC, Chylack LT Jr, Wu SY. The Lens Opacities Case-Control Study. Risk factors for cataract. Arch Ophthalmol 1991;109:244-51.
7. Lim R, Mitchell P, Cumming RG. Refractive associations with cataract: the Blue Mountains Eye Study. Invest Ophthalmol Vis Sci 1999;40: 3021-6.
8. Troilo D, Gottlieb MD, Wallman J. Visual deprivation causes myopia in chicks with optic nerve section. Curr Eye Res 1987;6:993-9.
9. McCarty CA, Nanjan MB, Taylor HR. Attributable risk estimates for cataract to prioritize medical and public health action. Invest Ophthalmol Vis Sci 2000;41:3720-5.
10. Weale R. A note on a possible relation between refraction and a disposition for senile nuclear cataract. Br J Ophthalmol 1980;64:311-4.
11. Wong TY, Klein BE, Klein R, Tomany SC, Lee KE. Refractive errors and incident cataracts: the Beaver Dam Eye Study. Invest Ophthalmol Vis Sci 2001;42:1449-54.
12. Perkins ES. Cataract: refractive error, diabetes, and morphology. Br J Ophthalmol 1984;68:293-7.
13. Tuft SJ, Bunce C. Axial length and age at cataract surgery. J Cataract Refract Surg 2004;30:1045-8.
14. Belkin M, Jacobs DR, Jackson SM, Zwick H. Senile cataracts and myopia. Ann Ophthalmol 1982;14:49-50.
15. Shammas HJ, Milkie CF. Mature cataracts in eyes with unilateral axial myopia. J Cataract Refract Surg 1989;15:308-11.
16. Wallman J. Retinal influences on sclera underlie visual deprivation myopia. Ciba Found Symp 1990;155:126-34.
17. Meyer C, Mueller MF, Duncker GI, Meyer HJ. Experimental animal myopia models are applicable to human juvenile-onset myopia. Surv Ophthalmol 1999;44 Suppl 1:S93-S102.
18. Fisher RF. Senile cataract: a comparative study between lens fibre stress and cuneiform opacity formation. Trans Ophthalmol Soc UK 1970;90: 93-108.
19. Weale R. A note on a possible relation between refraction and a disposition for senile nuclear cataract. Br J Ophthalmol 1980;64:311-4.
20. Micelli-Ferrari T, Vendemiale G, Grattagliano I, Boscia F, Arnese L, Altomare E, et al. Role of lipid peroxidation in the pathogenesis of myopic and senile cataract. Br J Ophthalmol 1996;80:840-3.
21. Simonelli F, Nesti A, Pensa M, Romano L, Savastano S, Rinaldi E, et al. Lipid peroxidation and human cataractogenesis in diabetes and severe myopia. Exp Eye Res 1989;49:181-7.
22. Dovrat A, Ding LL, Horwitz J. Enzyme activities and crystallin profiles of clear and cataractous lenses of the RCS rat. Exp Eye Res 1993;57: 217-24.
23. Babizhayev MA, Deyev AI. Lens opacity induced by lipid peroxidation products as a model of cataract associated with retinal disease. Biochim Biophys Acta 1989;1004:124-33.
24. Zigler JS Jr, Bodaness RS, Gery I, Kinoshita JH. Effects of lipid peroxidation products on the rat lens in organ culture: a possible mechanism of cataract initiation in retinal degenerative disease. Arch Biochem Biophys 1983;225:149-56.
25. Goosey JD, Tuan WM, Garcia CA. A lipid peroxidative mechanism for posterior subcapsular cataract formation in the rabbit: a possible model for cataract formation in tapetoretinal diseases. Invest Ophthalmol Vis Sci 1984;25:608-12.
26. Liang H, Crewther DP, Crewther SG, Barila AM. A role for photoreceptor outer segments in the induction of deprivation myopia. Vision Res 1995;35:1217-25.