NUTRITION AND AGE-RELATED LENS OPACITIES (CATARACT)

INTRODUCTION

Cataract is an opacification of the lens of the eye (Figure 1), which results in diminished visual acuity and can lead to blindness[1].

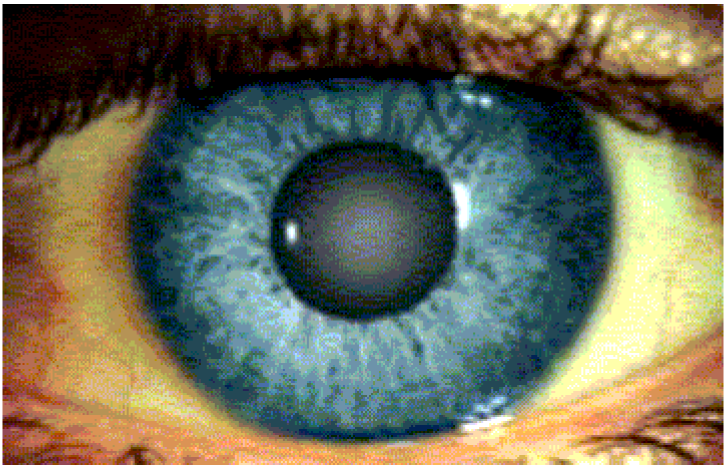

Figure 1: Adult lenticular opacity (Cataract)

Globally, almost 16 million people worldwide are blind, and some 50 million have impaired vision, as a result of cataracti[i]. The prevalence of cataract-related blindness in some countries (Table 1)[2] indicates that almost half of the population has cataracts that impair vision by the age of 75 years[3,4]. In developing countries, a similar prevalence is seen by the age of 50 years. In terms of treatment, in the USA more than two million lens extractions are performed annually[5] with the attendant significant health care costs (US $ 5 billion)[6]. In South Africa, it is currently estimated that more than 250 000 individuals are in need of treatment and an active campaign has been implemented to address the problem. Cataracts occur more frequently with increasing age and are an important cause of disability among older adults. Importantly, the significance of the disorder should be seen against the worldwide trend of an increasing elderly population. Current estimates indicate that by the year 2010, more than 20% of the population in industrialised countries will be over 65 years of age[7].

Table 1: Prevalence of cataract-related blindness in selected countries

Region	Population (thousands)	Prevalence of blindness (%)	Cataract-related blindness/100 blind
Africa			
Chad	5680	2.3 [a]	48
Congo	2276	0.3 [a]	81
Gambia	875	0.7 [a]	55
Eastern Mediterranean			
Saudi Arabia	14870	1.5 [a]	55
Tunisia	8060	3.9 [b]	52
South-East Asia			
India	849515	0.7 [a]	81
Indonesia	178232	1.2 [a]	70
Nepal	18916	0.8 [a]	67
Thailand	55853	1.1 [a]	57
Western Pacific			
China	1333698	0.4 [a]	52
Japan	123519	0.3 [b]	23
Philippines	61480	0.8 [a]	87

[a] Less than 3/60 in better eye.
[b] Less than or equal to 6/60 in better eye.

DISCUSSION

The lens of the eye is a very unusual organ (Figure 2). It has no nerves or a blood supply. Nutrition and removal of breakdown products take place through the aqueous humour. It also has only a limited capability for repair. The lens achieves its transparency through its special structure. It has only two types of cells: a single layer of epithelial cells under the front surface of the membranous capsule and fibre cells. The lens fibres comprise more than 90% of the lens bulk.

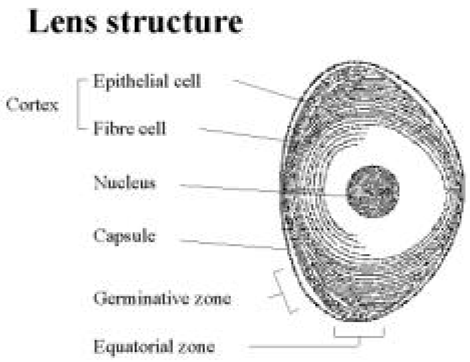

Figure 2: Cross-section of a mammalian lens showing the typical structure.

Epithelial cells in the germinative region divide, migrate backwards, and differentiate into lens fibres. These have no nucleus or other organelles, and contain a large proportion of unique structural proteins called crystallins. The lens continues to grow throughout life. As new fibres are produced, they overlay the older ones, pushing them towards the centre, or nucleus, of the lens. In the process, they are dehydrated and compressed, and metabolic activity ceases.

The arrangement of the densely packed crystallins ensures a uniform refractive index in the lens, allowing light to pass in a straight line. Unlike other organs, which quickly remove damaged cells and unwanted molecules, the lens seems to have this ability only during youth. The adult lens still contains fibres produced before birth.

The aetiology of cataract remains still largely unclear and is thought to be multifactorial. Available research findings indicate that cataract formation is associated with low socio-economic and educational status, small stature, excessive exposure to light, heat, smoking and other environmental stresses as well as some medical disorders such as diabetes, hypertension, renal failure and dehydration. It is likely that various factors interact in the formation of cataracts, but it is difficult to interpret the influence of each factor independently. The matter is made more complicated by the fact that no uniform explanation has been found for the different types of cataract (nuclear, cortical, and posterior subcapsular). In relation to nutrition, certain nutritional deficiencies have been proposed (Table 2) as being contributory, but knowledge is rather limited as to when and why protein degeneration in the lens begins. The induction period is thought to be extremely long. It has been suggested that nutritional deprivation or an insult to the lens protein before or soon after birth may trigger the process[8]. Evans et al.[9] provided evidence supporting this hypothesis by assessing the relationship between early growth and cataract formation. In a population of 1428 English men and women aged 64–74 years, body weight at 1 year was negatively correlated with nuclear opacity score in adult life ($P = 0.001$). The association remained after controlling for age, sex, smoking, social class, adult height and diabetes. The authors, however, found no association for cortical or posterior subcapsular opacities, which were less common in the study population.

Table 2: Nutrients involved in antioxidant defence systems and thought to protect against cataract formation

Nutrient	Function	Reasonable daily supplement
Vitamin C	Major antioxidant in cytosol and extracellular fluids; regenerates vitamin E	200–1000 mg
Vitamin E	Main antioxidant in membranes (lipoproteins); sparing effect on beta-carotene	100–300 mg
β-carotene	Potent quencher of singlet oxygen	3.0–6.0 mg
Riboflavin	Cofactor for the enzyme glutathione reductase	2.0–3.0 mg
Niacin	Cofactor in many redox reactions	20–40 mg
Zinc	Essential constituent of superoxide dismutase	15–20 mg
Selenium	Essential constituent of glutathione peroxidase	70 µg

Like all biological systems, the lens is subject to oxidant damage. Oxidants and other chemicals arising from metabolic activity or the environment can react with and damage membranes and structural proteins of the lens. As the lens ages, damaged proteins accumulate, progressively increasing light scattering and leading to cataract. However, the rate at which these changes occur is variable, and many people maintain visual acuity to an advanced age. Certainly, oxidative stress appears to play a key role in cataract formation[6]. Oxidation is a vital process in energy metabolism and biological defence systems. It also produces highly reactive metabolites (free radicals, hydrogen peroxide and singlet oxygen) that can cause serious cellular injury if the body's antioxidant defences are compromised. Important sources of reactive oxygen metabolites in the lens are ultraviolet and ionising rays from sunlight.

In young lenses, damaged proteins are usually maintained at harmless levels by defence systems. Primary defences include vitamin C, vitamin E, carotenoids, glutathione and enzymes (superoxide dismutase, catalase, and the glutathione redox cycle). Secondary defence systems include proteolytic enzymes that selectively identify and remove damaged or obsolete proteins. In older lenses, however, accumulation of damaged proteins indicates that antioxidant defence systems may be impaired and contribute to cataract formation. Antioxidant levels in such lenses are reduced and enzyme activity is impaired. In this regard, levels of vitamin C in human lenses are about thirty times higher than in the plasma, and are dependent on dietary intake[10]. Cataractous lenses have significantly reduced levels of vitamin C[11]. On the other hand, vitamin E and beta-carotene levels are not increased in the lens.

A number of epidemiological studies have examined the associations between cataract and antioxidant nutrients[6]. Several of these studies have shown a decreased cataract risk in people with high dietary or supplemental intakes of antioxidant nutrients, as well as in those with high plasma levels of these nutrients. However, the findings of a protective effect have not been consistent and the interpretation of these findings is limited by the wide variety of methods used and parameters measured. Nevertheless, dietary and supplemental intakes of antioxidant micronutrients were monitored prospectively for four years in women with intact lenses recruited from the Nurses' Health Study (n = 50 828; 45 – 67 years of age). After eight years the incidence of cataract extraction was lower in women with high antioxidant scores[12]. Additionally, the consumption of a vitamin C supplement for more than 10 years conferred a significant 45% reduction in the risk of developing cataract. Another study using participants from the same cohort (n = 247 women; 56 – 71 years of age) measured the development of lens opacities in relation to long-term use of vitamin C supplements[13]. To eliminate bias due to the possible effect of cataract diagnosis on nutrition behaviour, vitamin C use was measured five times over a 10–12 year period before assessment of lens status. Vitamin C supplementation (400 - >700 mg daily) for at least 10 years was associated with a 77% lower prevalence of early lens opacities, and an 83% lower prevalence of moderate lens opacities.

The Longitudinal Study of Cataract measured changes in nuclear opacification over five years in 764 participants older than 40 years of age[14]. The risk of progression of nuclear cataracts was reduced by one-third and one-half in subjects who regularly consumed a multivitamin or vitamin E supplements respectively as well as in those with higher plasma levels of vitamin E. Contrary to these findings, however, an end-of-trial random sample of 1828 middle-aged male smokers in the Finnish ATBC study (alpha-tocopherol, beta-carotene cancer prevention study) showed no effect on cataract prevalence after five or eight years of supplementation with these nutrients[15].

Further support of a protective effect against developing age-related cataracts by antioxidant micronutrients and/or vitamin/mineral supplements has been derived from the two landmark cancer intervention trials in Linxian, China. Sperduto et al[16] conducted eye examinations at the end of these trials. In one study, subjects with œsophageal dysplasia were randomly assigned to receive a daily multivitamin/mineral/beta-carotene supplement or placebo for up to six years. Dosages were selected to shift the mean nutrient status of the participants near to that of the upper 10–20% of the US population. In the second trial, involving members of the general population, participants received one of seven different nutrient combinations or placebo for up to five years. Eye examinations were done on 2141 persons in the dysplasia trial and 3249 persons in the general population trial. Ages ranged from 45 to 74 years. In the dysplasia trial, participants over 65 years of age who took the supplements had a 36% lower prevalence of nuclear cataract. In the general population trial, prevalence of nuclear cataract was significantly lower in those who received a riboflavin/niacin supplement. Again, persons over 65 years of age benefited most (44% reduction). The results also suggested a protective effect for the retinol/zinc and the vitamin C/molybdenum supplements. No treatment effect was, however, noted for the prevalence of cortical cataracts (the commonest form) in either trial.

The totality of the available evidence would appear to support a protective role of antioxidant micronutrients and/or multivitamin/mineral supplements against lens opacification. The lack of consistency in the currently available findings, however, must surely reflect the multifactorial aetiology of the disorder and the limitations of the wide variety of the methodologies employed and the parameters measured as well as the need for the better understanding of the relationship. In this regard, current thinking on this relationship emphasises the need for and relative lack of prospective trials in its further elucidation. Two such recent surveys confirm the protective effect of vitamin E[17] and provide "new" evidence[18] of a certain specificity of the role of antioxidant micronutrients in relation to eye health. In the first trial (n = 400 adults; 50 – 76 years of age)[17], the possibility that nuclear cataracts may be inversely linked to vitamin E status is confirmed [odds ratio (OR): 0.4; 95% Confidence Interval (CI): 0.2, 0.9; $p = 0.03$ for linear trend], and, additionally, marginal inverse associations with lutein (OR: 0.3; 95% CI: 0.1, 1.2; $p = 0.13$ for linear trend) and cryptoxanthine (OR: 0.3; 95% CI: 0.1, 1.3; $p = 0.11$ for linear trend) is suggested in individuals older than 65 years of age. The second trial (n = 36 644; 45- 75 years of age)[18] confirms the protective effect of lutein [19% lower risk of cataract extraction; Relative Risk (RR): 0.81; 95% CI: 0.65, 1.01; $p = 0.03$ for trend) and affords a similar protective effect to zeaxanthin. Indeed, the authors indicate that among carotenoid-rich foods, broccoli and spinach were the most consistently associated with a lower risk of cataract.

SUMMARY

In summary, the approach to the prevention of a disorder with multifactorial aetiology should,by necessity be multifaceted. As such, weight control is not only a prudent measure for reducing the risk of cardiovascular disorders, it also helps to reduce the risk of developing hypertension and non-insulin-dependent diabetes and its known complication of senile cataract. Additionally, other measures should be taken to minimise exposure to damaging factors. The simplest of these is to wear eye protection (sunglasses, hat with a wide brim) while outdoors in the sun. It is also important to avoid exposure to environmental pollutants, such as tobacco smoke and organic solvents. Nutritionally, optimising one's diet to include foods (fresh fruits and vegetables, especially green leafy vegetables) known to be important in maintaining adequate antioxidant defences in particular vitamin C, vitamin E, carotenoids, riboflavin, niacin and selenium would seem to be appropriate and necessary. For adults, especially those unable or unwilling to consume sufficient amounts of the foods containing these nutrients, an appropriate dietary supplement should be considered under the expert supervision of a health professional.

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