A review of the evidence that ultraviolet irradiation is a risk factor in cataractogenesis

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Abstract. There are two approaches to the question of whether solar radiation contributes to human cataract. The first, epidemiological studies, investigates correlations between man's environmental UV dose and cataract frequency. The second, animal models, investigates the effects of varying UV strengths and spectra on lens opacification in vivo or in vitro. While the latter approach typically provides for direct evidence, the data must still be extrapolated to human lenses. Results of physiological studies suggest that UV photons interact with proteins of the epithelial cell membranes, in particular tryptophan residues, transport ATPases and cytoskeletal proteins. One hypothesis is that damage to ion pumps and channels accumulates over the years as repair processes incompletely restore membrane function. Peroxidative damage is likely in view of the formation of UV-induced lipid peroxides in the lens epithelial membranes. Loss of homeostatic control of ions, particularly Ca++, leads to crystallin disorder in small regions of the underlying fiber cells. In our diabetic cataract studies, intracellular Ca++ electrodes detected large shifts in intracellular Ca++ before bulk-lens changes were apparent. Similar occurrences likely characterize UV cataract. Our lab is one of few studying lens physiology and how it is altered following transient exposures to UV-B and UV-A, both of which pass through the cornea. Some changes include: loss of epithelial cell GSH; elevated Ca++; loss of membrane voltage; impaired transport of Na+; increased permeability to ions and water; inhibition of critical enzymes; and a decrease in the rate of membrane synthesis.

Introduction

That ultraviolet light contributes to some forms of human cataract is perhaps controversial, despite the studies on animal models [1–10] and a number of epidemiological studies [11–13] which provide indirect evidence that UV irradiation is a potential hazard to the lens. Most controversial perhaps are the epidemiological studies in which the usual aim is to determine whether the risk of cataract increases as UV exposure goes up. Some studies are designed to correlate prevalence of cataract with factors associated with the place of residence or employment. Unfortunately, numerous confounding factors complicate the analysis. A survey of the literature makes it clear that some studies show correlations of cataract incidence with sunlight UV exposure, some do not. The results are seldom dramatic or overwhelming, which makes the critic suspicious. On the other hand, most animal studies, including some on human lens proteins [5,10,14,15], demonstrate the damaging capabilities of UV irradiation. To the skeptic, however, animal studies are flawed in terms of excessive irradiance presented to the animal or lens; or, the particular species
studied is not sufficiently similar to the human lens; or, a wavelength was used which may not pass through the cornea. Before reviewing some of the more recent results from animal models not characterized by these shortcomings, it is useful to examine more closely some of the critic's concerns.

The first concern, regarding 'weak' epidemiological evidence, is quite legitimate in the sense that it has been difficult to provide adequate dosimetry data or to quantitate how much solar radiation actually enters the eye of subjects. Two people working on the docks over the water every day for 20 years do not necessarily receive similar fluences. Lid opening, environmental reflectance, the wearing of glasses and hats are just some of the variables which complicate the analysis. Many studies use surveys designed to estimate some measure of exposure for a particular occupation or lifestyle in the sun. But what about the UV exposures absorbed by youngsters? What about the children and their habits in the sun, for whom it is already suggested that epidermal exposure to UV put them at high risk for skin cancer in later years?

Add to this the potential complication of synergistic effects of compounds in the aqueous humor and in the environment, and correlation analysis becomes extremely difficult. The presence and undetermined strength of other environmental, nutritional or genetic factors that constitute cataractogenic stimuli might facilitate or suppress potential UV damage. Agents endogenous to the aqueous humor which are potential risk factors include hydrogen