# The Eye and Electromagnetic Radiation

Author's Bio
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Throughout our lifetimes we are all exposed to sunlight, which includes a broad section of the electromagnetic spectrum. Included in this section are ultraviolet light (UV), with wavelengths from approximately 295 nm to 400 nm, visible light (400-800 nm) and infrared (800-1200 nm) [1]. Sunlight and UV radiation can have both beneficial and detrimental effects on humans. Detrimental effects include aging of the skin, sunburn, skin cancer and cataracts. However, sunlight and UV exposure are beneficial for vitamin D development, which can affect bone health. Additionally, sunlight affects melatonin and serotonin production, which help regulate the body's circadian rhythm and may also contribute to overall health [2]. When considering UV rays we understand that the UV spectrum is divided into UVC rays (100-280 nm), UVB rays (280-315 nm), and UVA rays (315-400 nm). It has been well documented that UV radiation can damage the eye. Factors that affect the damage that the eye may incur include the wavelength of light, the intensity, duration of exposure, cumulative effect, angle of incidence, solar elevation in the sky, ground reflection, altitude, and the anatomy of the eyebrow and eyelids [1, 3]. Because of these factors, UV protection can be even more critical for those who spend long hours in the sun as well as during certain activities with high reflectance such as being in the snow or on the water [4, 5]. The American Macular Degeneration Foundation emphasizes protection for construction workers, farmers, truck drivers, law enforcement officers, life guards, and those involved in outdoor sporting activities such as skiing and beach activities [6]. Also, individuals who require and take certain medications, such as tetracycline, sulfa drugs, birth control pills, diuretics and tranquilizers should consider the use of UV protection due to the increased light sensitivity caused by these treatments [5].

The higher energy shorter wavelengths are the most harmful, but fortunately the earth's atmosphere absorbs and scatters much of these harmful wavelengths of UV light. Moreover, the various structures of the eye have different filtering and absorption characteristics. It has been reported that of the shorter wavelengths that reach the eye, the cornea absorbs 100% of UVC, approximately 90% of UVB, and 60% of UVA incident rays. The majority of the UVA that is not absorbed by the cornea is absorbed by the crystalline lens and only a small portion of the UVA reaches the retina. The cornea and lens do not significantly filter short high energy visible (HEV) wavelengths such as violet and blue and the majority of these wavelengths reach and are absorbed by the retina and retinal pigment epithelium [1]. When the eye is damaged from UV and HEV light, the damage is a result of solar radiation, oxidation, and heat-causing deterioration [7].

Retinal light damage can occur through photothermal, photomechanical, or photochemical mechanisms. Photothermal damage is caused by the longer wavelengths in the visible spectrum as well as those in the near infrared region. Damage occurs when the retinal temperature is increased by greater than 10° C above the ambient retinal temperature. When energy is absorbed by melanin pigment in the retinal pigment epithelium (RPE) and choroid, damage results by breaking of chemical bonds. Photomechanical harm is caused by a rapid absorption of energy by melanin in the RPE, during which heat dissipation cannot occur, resulting in mechanical forces which cause damage to the photoreceptors and the RPE. This type of damage is determined by the rate of delivery and the quantity of energy, not the wavelength. Photochemical damage is caused by exposure to the high energy portion of the visible spectrum and UVA and may result in damage to the photoreceptors and the RPE, the formation of free radicals or reactive oxygen species (ROS), damage to the mitochondrial DNA and eventually cell death [8- 10]. Controlled retinal light damage can also be used therapeutically. Examples of ophthalmic lasers using photothermal principles include transpupillary thermotherapy (TTT) for choroidal melanomas, Krypton or Argon laser photocoagulation and micropulse diode lasers.

The Nd:Yag laser used for treatment to create an iridotomy as well as a capsulotomy are examples of photomechanical light damage. Photodynamic therapy (PDT) is an example of photochemical damage used therapeutically [8, 10].

Because of the concerns of ocular damage with exposure to certain regions of the electromagnetic spectrum, recommendations by various health care organizations have been developed. According to the United States Environmental Protection Agency (EPA) overexposure to UV light may lead to skin cancer, premature aging of the skin, cataracts and other eye damage such as photokeratitis, and pterygium. In addition, they also note that children are particularly at risk. The EPA has developed the *SunWise* program which provides environmental and health education. Through this program, in partnership with Prevent Blindness America, they strive to develop continued “sun-safe” behaviors in children. Recommendations include good fitting frames that shield the eye from most angles and lenses that block 99-100% of UVA and UVB rays. On top of that, they recommend wide brimmed hats to reduce the amount of eye exposure to UV light [4, 11]. The Centers for Disease Control and Prevention (CDC) also recommends wrap around sunglass with UV protection which blocks UVA and UVB for children when outdoors [12]. Recommendation by the National Eye Institute of the National Institutes of Health, as well as the United States Department of Labor, Occupational Safety and Health Administration (OSHA), also suggest sunglasses that block 99-100% of UVA and UVB radiation to protect the eyes [13. 14]. The American Public Health Association also supports education regarding the harmful effects of UV through health promotion and disease prevention programs. In addition, they encourage public health education and support government and professional organizations in developing, monitoring and implementing practical and evidence based guidelines regarding UV exposure [15]. Although the above recommendations and guidelines are meant to provide maximum protection, compliance and implementation are left to each individual. However, by promoting education and awareness, hopefully positive changes in health behavior will occur as informed individuals begin to make prudent decisions.

Moreover, as mentioned previously, there are many variables that can affect the amount of UV that reaches the earth’s surface. These can include variation in the weather and seasons as well as depletion of the ozone layer. The UV index which was developed by the National Weather Service and the EPA, determines the magnitude of solar UV radiation by area each day. The risk of harm from sun exposure is presented on a scale of 1 to 11+; with 1-2 indicating low risk, 3-5, moderate risk; 6-7, high risk; 8-10, very high risk; and 11+, extreme risk [16]. The index is issued on the EPA website in the afternoon, Eastern Time, for the next day. The information is presented in many forms, including a UV alert map, cities forecast bulletin, by zip code, or by city and state. In addition there are resources provided by the EPA for email notification, smartphone notification apps, as well as widgets for website development [16]. The UV index is also sometimes reported on TV, radio, or by newspapers along with the weather forecast [17]. Internationally, the World Health Organization (WHO) promotes the consistent use of the UV index through their *INTERSUN Programme*, using an international color code for various index values as well as universally recognizable graphics representing the recommended protection for the various levels [17], (Figure 1).

When considering retinal damage, it has been shown that short wavelength and blue light can cause notable oxidative stress to the retinal pigment epithelium, damage to the photoreceptors, and cell death [9, 18]. When investigating UV light exposure and macular degeneration, some studies have found a clinical correlation while others have not [18]. However, in individuals who are aphakic or pseudophakic with incomplete UV absorbing intraocular lenses (IOLs), UV energy may be more damaging and protection is indicated [7, 19]. Another consideration is children, who may spend more time outdoors than adults, and whose young lenses do not absorb as much UV light as adult lenses [7, 20].

Several animal studies [21-23] and in vitro studies [24-26] have revealed evidence of damage to retinal cells from blue light exposure. Studies have also demonstrated that filters that block blue light can offer protection against light induced retinal damage [23, 26]. Others have raised possible concerns with blue filters affecting the body’s circadian rhythm [27-29]. Further, it has been well documented that carotenoids in macular pigment such as lutein, zeaxanthin and meso-zeaxanthin offer protection to the retina due to their propensity to filter high energy blue light and protect from potential damage by scavenging reactive oxygen species formed from exposure to light [10, 30-32].

Epidemiologic studies have shown varied findings. The Blue Mountain Eye Study, a population-based evaluation of individuals in communities in Australia, revealed that the long-term risk of age related maculopathy is higher in cataract surgical eyes. [33]. The Beaver Dam Eye Study conducted in Beaver Dam, Wisconsin beginning in 1988, also found an association of cataract surgery with late age-related macular degeneration [34]. The Chesapeake Bay Watermen study originating in 1985 in Maryland, established that compared to controls, individuals with advanced age-related macular degeneration were not significantly different regarding UVA or UVB exposure, but revealed significantly greater exposure to visible or blue light during the prior 20 years [35, 36]. Others have noted that sunlight exposure has not been definitively established as an age-related macular degeneration (AMD) risk factor and suggest that further investigation is needed in this area, particularly clinical trials to investigate the possible preventative effects of blue light filtration on AMD. They do note however that it could be reasonable to wear UV-filtering sunglasses to provide comfort, decrease exposure to ocular structures and possibly provide protection against cataract development [37].

Research studying the detrimental effects of UV light on the eye has been ongoing for decades. Some evidence is not conclusive and some controversial. A review of the literature reveals conflicting opinions on the exact relationships between solar UV and/or HEV light exposure and ocular damage. The World Health Organization recognizes that solar UV radiation has shown a causative role in photokeratitis, photoconjunctivitis, pterygium, squamous cell carcinoma of the cornea and conjunctiva, cortical cataracts and acute solar retinopathy [38]. Others have also noted a relationship between UV exposure and many of these ocular conditions [3,7,39]. The World Health Organization notes conflicting evidence concerning posterior subcapsular cataract and solar UV exposure, and insufficient evidence to solidify a causal relationship between solar UV exposure and climatic droplet keratopathy (spheroidal degeneration), pinguecula, nuclear cataract, or with ocular melanoma. Finally, they also conclude that the evidence connecting solar UV exposure and acute macular degeneration is very weak. They do however suggest that further evaluation is needed to investigate a possible association between excess solar UV exposure and acute macular degeneration [38].

While the literature may report conflicting results on the effects of UV and/or HEV light exposure and some ocular conditions, further studies are needed to understand these relationships more definitively. Many ocular conditions however reveal a consensus on the detrimental effects of UV radiation. There are currently many lens choices available to provide added protection and comfort against UV light and sunlight in general. Lens materials such as polycarbonate, Trivex and many high index materials used today filter a large percentage of UV light [40]. Many IOLs and contact lenses also provide some protection against UV light [41 -43]. However, in these situations, UV sunglasses are recommended in addition to the IOLs and contact lenses as they provide a broader area of protection, especially to the eyelid skin, sclera and conjunctiva. In the case of IOLs, in addition to the structures stated, sunglasses can also provide protection to the cornea and iris. When protection from HEV light is desired, there are several lens coatings as well as specific sunglass lens designs which provide protection [29, 44, 45]. Also, when considering lenses that block HEV light it is important to choose lenses that do not affect color vision significantly and are therefore safe for driving. The style and shape of the frame is also important to provide adequate protection from peripheral light exposure. It has been reported that small sized sunglasses alone may actually increase UV exposure peripherally due to the reduction of the body’s habitual protective mechanisms of lid squinting and pupillary constriction. Because of this increased risk, wrap- around sunglass lenses offering side protection as well as a brimmed hat offering overhead protection have been advised [3, 46]. Use of UV filtering soft contact lenses has been shown to help reduce problems from peripheral light focusing. Usage of these contact lenses in conjunction with sunglasses and a hat may offer maximal protection [47].

In summary, while much is known about the effects of UV and HEV light on ocular structures, further studies are needed to fully understand these relationships completely. In particular, with the concerns of UV and HEV light and their effect on the retina, clinical trials and long-term studies are necessary. However current technology provides us with lenses that filter both UV and HEV light. In the advent of digital technology, we have become increasingly dependent on devices such as computers, tablets and smart phones. Concerns about the levels of blue light emitted from these devices, especially with the long hours spent viewing them by individuals of all age levels, may become relevant. Expanding our knowledge and understanding of these possible relationships are essential [29]. In the meantime, the information that we currently know and the options available, are important to convey to our patients to help them make informed decisions.

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