

# RETINAL LIGHT EXPOSURE AFTER CATARACT SURGERY, WHAT ARE THE RISKS?

Phototoxicity is a current vision health concern and there is evidence that UV and blue-violet light may cause adverse effects to the eye. Blue-violet light sources include the sun, but also the widespread light-emitting diode (LED) technologies, resulting in around-the-clock exposure. Chronic exposure to blue-violet light, among other factors, may contribute to retinal diseases such as age-related macular degeneration (AMD), or speed-up AMD progression after cataract surgery, because of increased transmission of short-wavelength light. This link has not been definitively proven, due to a lack of clinical trials. Nevertheless, it has been shown that photoprotective measures such as blue-blocking IOLs or spectacles with blue-violet filtering lenses have no detrimental effects, making them a sensible choice in high-risk patients or patients with a longer pseudophakic life.



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## KEYWORDS

Light exposure, blue-violet light, light-emitting diodes (LED), cataract surgery, retina, photoprotection, blue-blocking intraocular lenses (IOL), age-related macular degeneration (AMD)

The risks of ocular light exposure are a current concern and health providers are frequently faced with questions on this topic. With recent advances in lighting sources and technology, modern man's environment includes not only exposure to light in the form of solar radiation but also in the form of domestic lighting.<sup>1,2</sup>

Sunlight is the main source of ultraviolet (UV) radiation which is composed of electromagnetic radiation with wavelengths from 100 nm to 380 nm, while visible light ranges from 380 to 780 nm.<sup>3</sup> Long-term exposure to UV radiation is known to cause anterior segment diseases such as keratitis, pterygium, cataracts and melanoma.<sup>4,5</sup> Also, within the visible light spectrum, blue light exposure (380-500 nm) has been linked to photoreceptor and retinal pigment epithelium (RPE) toxicity<sup>1,4-8</sup> and can induce a photochemical reaction culminating in cell apoptosis.<sup>8</sup> This phenomenon is referred to as the "blue light hazard" and has a peak at 440 nm<sup>8,9</sup>. Recent *in vitro* studies have demonstrated the phototoxic action spectrum in a RPE model of age-related macular degeneration as ranging from 415-445 nm with a peak at 435 nm.<sup>10</sup> As far as artificial light is concerned, LEDs have evolved significantly in the last two decades and not only have replaced traditional lamps in the domestic setting, but have also become the primary light source in tablets, TVs, computers and smartphones. The LEDs emit in the blue light spectrum (380-500 nm) and therefore increase the exposure of the human eye to harmful radiation.<sup>1,2,7,11</sup>

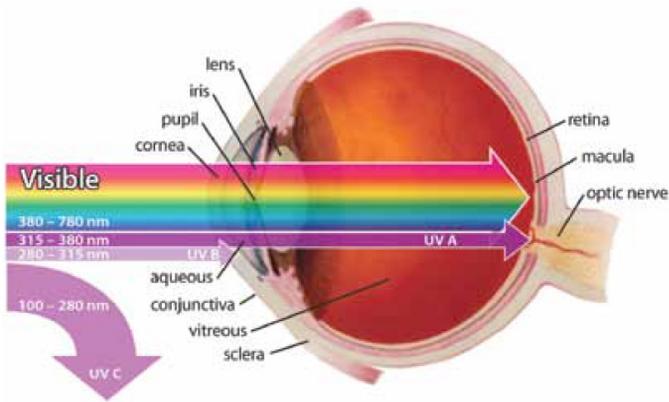


FIG.1| Light exposure to the eye

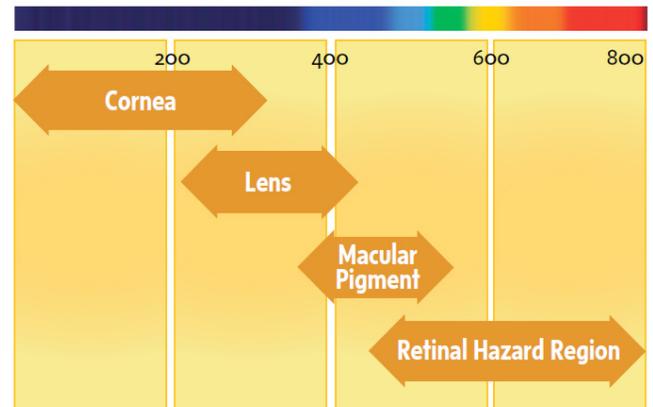


FIG.2| Absorption of light radiation by different ocular structures

Nevertheless, the eye has defences against phototoxicity. The cornea and crystalline lens naturally protect the retina and the posterior ocular structures against different sources of radiation, with less than 1% of UV light reaching the retina<sup>4,8,12</sup>, while the macular luteal pigment attenuates the blue light that reaches the retina, mainly at 440 nm<sup>1</sup> (Figure 1 & 2). Also with age, the yellowing of the crystalline lens leads to increased short-wavelength light blockage, partially protecting the aged retina and RPE. This protective effect disappears with cataract surgery, which is now one of the most common ocular procedures worldwide.<sup>8,9,12</sup>

This article discusses the potential risks of light exposure on the retina after cataract surgery and photoprotective solutions.

### 1. Cataract surgery

Cataract surgery technology has been continuously evolving in order to allow safer and more predictable outcomes. Advances are not only at the level of preoperative and intra-operative testing, but also include femtosecond laser-assisted cataract surgery (FLACS) and improvements in intraocular lenses (IOLs).<sup>13</sup>

#### • IOLs

In cataract surgery, the yellowed aged lens (Figure 3) is removed and replaced by an IOL (Figure 4). IOLs have been modified over time to try to compensate for the properties of the removed crystalline lens. The first IOLs did not block UV light, however this obstacle was overcome by the 80s following concerns over retinal toxicity. Since then, transparent UV-blocking IOLs have been widely

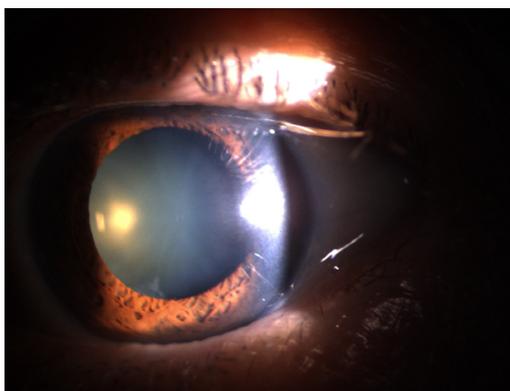


FIG.3| External photograph of the eye depicting a cataract.

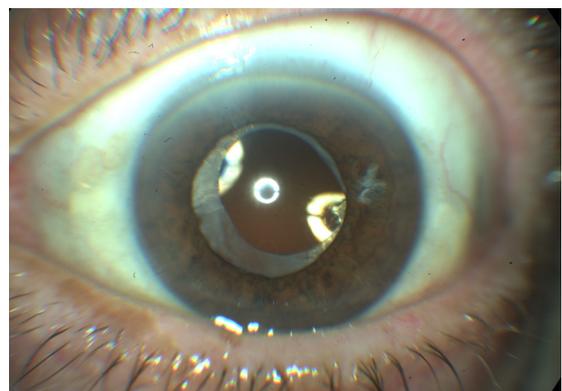


FIG.4| External photograph of the eye after lens replacement with an intra-ocular lens following cataract surgery.



«Regarding the association between light exposure and retinal disease in humans, the main attention has been on age-related macular degeneration, but some studies have also focused on pre-existing retinopathy and inherited retinal diseases.»

accepted.<sup>12</sup> Later, further knowledge that blue light exposure could also contribute to retinal damage, led to the introduction of blue-blocking IOLs, which are yellow-tinted, and block both UV light and blue-violet wavelengths (380-500 nm), mimicking healthy crystalline lenses.<sup>12,14</sup> The protective effect of these lenses on the retina has been well demonstrated by both animal and experimental studies.<sup>14-19</sup>

However, contrary to simple UV-blocking IOLs, these lenses have been the subject of debate because of their photoprotective benefit in humans and their impact on the circadian rhythm, scotopic and color vision.<sup>12-14</sup> Enthusiastic users claim there is decreased risk of age-related macular degeneration (AMD), reduced glare disability and improved photostress, without compromising contrast perception, color vision, scotopic vision, contrast sensitivity and circadian rhythm.. Opponents report there is no evidence of increased photoprotection against AMD and negative impact on sensory and physiologic factors.<sup>12-14,20,21</sup> While it has not yet been definitively proven that blue-blocking IOLs are photoprotective in humans,<sup>12,21,22</sup> the majority of studies involving them have not shown changes in scotopic vision, color and contrast vision or the circadian rhythm, making it safe to opt for the blue-blocking IOLs.<sup>12,14,20-25</sup>

## 2. Evidence of retinal phototoxicity and post-cataract risks for the retina

Replacement of the natural lens with an IOL implant increases retinal exposure to visible light and UV.

Many experimental and animal models have demonstrated retinal susceptibility to light exposure and blue light hazard.<sup>8,12,15,18</sup> Light has a detrimental effect on photoreceptors and RPE, inducing cell damage.<sup>8</sup> Recent studies have also shown retinal lesions following exposure to ubiquitous LEDs by inducing oxidative stress<sup>26</sup> and various countries, such as the UK, have created dedicated groups to determine the potential health risks of these new light sources.<sup>1</sup>

Regarding the association between light exposure and retinal disease in humans, the main attention has been on AMD, but some studies have also focused on pre-existing retinopathy and inherited retinal diseases.<sup>27</sup>

### • Age-related macular degeneration (AMD)

AMD is the leading cause of irreversible blindness in the elderly in developed countries.<sup>28-30</sup> It has been established that it is a complex multifactorial disease associated with demographic, genetic, and environmental risk factors.<sup>28,30</sup> AMD has two forms: dry (nonvascular or atrophic) (Figure 5) and wet (neovascular or exudative) (Figure 6).<sup>29,31</sup>

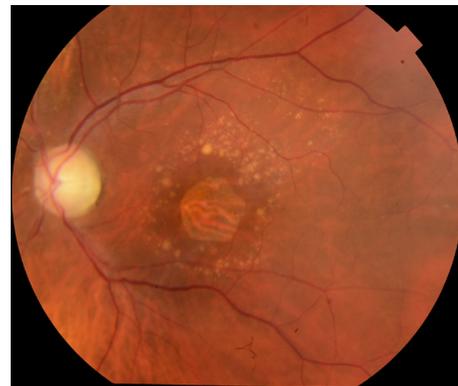


FIG.5] Color fundus photograph of dry age-related macular degeneration

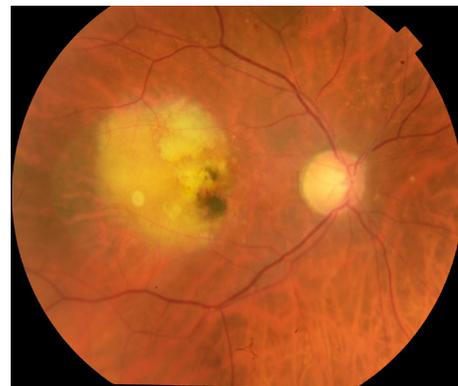


FIG.6] Color fundus photograph showing wet age-related macular degeneration.

Recent studies estimated that AMD will affect about 196 million people in 2020 and 288 million in 2040,<sup>32</sup> emphasizing the need for improved treatment and preventive measures.<sup>12</sup>

Light exposure has been implicated in macular toxicity and as an environmental risk factor for the development of AMD, in both experimental and animal studies. Phototoxicity induces oxidative stress and photoreceptor apoptosis which damages the ageing retina.<sup>8,10,12,26,28,29,33</sup>



«Regarding the post-cataract risk of AMD progression, the literature shows conflicting results»



FIG.7] Color fundus photograph of Stargardt disease, right and left eye (top and bottom, respectively).

This injury is cumulative and appears to be mediated by the lipofuscin chromophore A2E, therefore increasing with the amount of lipofuscin present.<sup>10,15</sup>

Nevertheless, the evidence in humans supporting the hypothesis that environmental light exposure is associated with AMD progression is controversial.<sup>12,22</sup> While some studies support the relationship,<sup>5,9,34-36</sup> the Beaver Dam Eye Study found few significant relationships<sup>37-39</sup> and other important epidemiology studies found no association.<sup>40-44</sup>

Regarding the post-cataract surgery risk of AMD progression, again the literature describes conflicting results.<sup>45-47</sup> The major epidemiology studies report prevalence and have different results when considering early or advanced disease or dry versus wet AMD.

The Beaver Dam Eye Study found an association between cataract surgery and late AMD<sup>48,49</sup> and combined data from three other population-based studies also found this association, but advised caution when interpreting the

data.<sup>50</sup> A combined analysis from the Beaver Dam and the Blue Mountains Study, two large epidemiology studies, showed that the prevalence of advanced AMD was higher in pseudophakic versus phakic eyes (6.7% versus 0.7%, respectively) and also supported the hypothesis that cataract surgery may be associated with late AMD.<sup>51</sup> Similarly at 10 years follow-up in The Blue Mountains Study, patients who underwent cataract surgery showed an increased long-term risk of developing late AMD.<sup>52</sup> In contrast, the Rotterdam Eye Study found an association with early AMD<sup>53</sup> and some studies,<sup>12,54-57</sup> including the Age-Related Eye Disease Study (AREDS)<sup>58,59</sup> and the Visual Impairment Project,<sup>60</sup> found no relationship. A Cochrane review<sup>61</sup> and a meta-analysis<sup>62</sup> also found no conclusive evidence of association.

It should also be taken into consideration that some cases of AMD might not have been recognized pre-operatively because of significant lens opacity or that the primary cause for visual loss was AMD and that these pathologies frequently coexist.<sup>54,62</sup>

#### • Inherited retinal diseases

Light deprivation has in the past been considered a possible treatment for some patients with inherited retinal diseases, although no therapeutic benefit has been demonstrated. As current knowledge in understanding the genes involved in these diseases increases, there have been suggestions of the value of light deprivation in selected cases.<sup>27</sup>

#### Autosomal dominant retinitis pigmentosa (ADRP)

Rhodopsin mutations are a frequent cause of ADRP with several mutations, including P23H, causing a distinctive phenotype with regional variation of retinal damage - classified by Cideciyan et al as class B1.<sup>63</sup> In line with this animal models of class B1 ADRP have demonstrated modification of degeneration by light, which was also supported by reports of familial cases with the P23H mutation.<sup>64</sup> The hypothesis is that light increases retinal degeneration by photoreceptor toxicity or interaction with the mutated rhodopsin.<sup>27,65</sup>

#### Oguchi Disease

Oguchi disease is a rare autosomal recessive disorder caused by mutation in either rhodopsin kinase (RK) or arrestin. It is characterized by congenital stationary night

blindness and the Mizuo-Nakamura phenomenon, in which the retina exhibits a yellow-gray discoloration in the presence of light that disappears with dark-adaptation and reappears with new light exposure. Studies with animal models for Ogushi disease suggested that light exposure could be an important modifier, at least in patients with the arrestin mutation.<sup>27</sup>

### Stargardt disease

Stargardt disease is an autosomal recessive disease caused by mutations in the ABCA4 gene (Figure 7). Animal models lacking the ABCA4 gene exhibit visual cycle abnormalities, which include high levels of A2E, which has been demonstrated to be retinotoxic.<sup>10,15,27</sup> As A2E levels are modulated by light and rhodopsin activation, light restriction may have a role in this context.

In clinical practice, it may therefore be prudent to minimize retinal exposure to light during examinations, imaging and ocular surgery<sup>27</sup> and to consider the use of ophthalmic lenses that filter blue-violet light. It should also be taken into consideration that some inherited retinal diseases are complicated by early cataracts so photoprotective measures may also be recommended after cataract surgery.<sup>66</sup>

### Conclusion

In conclusion, phototoxicity is a current vision health concern and it has been demonstrated that UV and blue-violet light have deleterious effects on the eye. In the past, the exposure was limited to daily hours, but with artificial lighting and current technologies, exposure is around-the-clock, potentially putting the eye at a higher risk. Currently, there is still lack of consensus between the relationship of light exposure and retinal diseases, such as AMD, as well as in terms of progression after cataract surgery caused by increased transmission of short-wavelength light. However it has been well demonstrated that the use of photoprotective measures such as blue-blocking IOLs have no detrimental effects. Therefore, despite the ongoing debate, it can be considered reasonable to use IOLs or spectacles with lenses that filter blue-violet light if not in all patients, at least in those at the highest risk and in younger patients with a longer pseudophakic life. Further controlled prospective studies are needed. •



### KEY TAKEAWAYS

- UV and blue-violet light can have deleterious effects on the eye
- Blue-violet light sources include sunlight and light-emitting diodes (LEDs)
- With artificial lighting exposure is around-the-clock, increasing the risk of phototoxicity
- Light exposure may be associated with retinal diseases and age-related macular degeneration (AMD)
- Cataract surgery may be associated with AMD progression, although the literature is conflicting
- Photoprotective measures, such as blue-blocking IOLs or spectacles with clear ophthalmic lenses that filter UV and blue-violet light, do not have detrimental effects
- Therefore, the use of lenses with appropriate filters is reasonable despite the lack of clinical trial evidence, especially in advanced AMD cases or younger patients with a longer pseudophakic life

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