Ultraviolet radiation and the eye

Exposure to UV radiation can have many adverse health effects, and the incidence of sun induced degenerative and neoplastic changes in the eye and surrounding structures continues to increase. Ocular sun protection is of prime importance.

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Numerous eye diseases are caused by exposure to UV radiation. The most common problem arising from acute exposure is solar keratitis, whereas chronic UV exposure may induce degenerative disorders such as pingueculae, corneal degeneration and cataract. Alterations in cell maturation and proliferation such as pterygium and neoplastic disorders of the eyelid skin can also result.

This article discusses a range of problems that can result from UV exposure and outlines some suggestions for protecting the skin and eye. The box on page 25 provides some background information about this type of radiation and its effects on biological systems.

Acute exposure

Solar keratitis

Solar keratitis presents as an acute corneal burn similar to an acute sunburn of the skin (Figure 1). The same mechanism leads to 'snow blindness', which is caused by a large dose of UV radiation being reflected off snow (or occasionally sand or water), and to 'welder's flash', which is caused by unprotected electric arc welding.

Solar keratitis is treated by recognition (exclusion of a corneal foreign body), relieving ciliary spasm using cycloplegic eyedrops, applying ocular lubricants and patching the eye. Narcotics may be necessary for acute pain. It generally resolves within 12 to 24 hours.

Chronic exposure

Pingueculae

Pingueculae are conjunctival disorders that generally do not cause problems (Figures 2a and b). They may, however, be associated with mild discomfort caused by roughness of the overlying surface, and their yellowish, raised appearance can be unsightly. The underlying pathology is elastotic degeneration of the subconjunctival tissues.

Pterygia

Pterygia may be seen in any age group, although the damage is usually done to the conjunctiva by

IN SUMMARY

- **Solar keratitis is the most common problem arising from acute exposure to UV radiation.**
- **Many eye diseases are caused by chronic exposure to UV radiation. Degenerative disorders may be irritating and at times visually disabling. Neoplasia of the ocular structures has a high degree of ocular, and even patient, morbidity.**
- **The combination of wraparound, UV-absorbing sunglasses and a broad brimmed hat provides the best protection against ocular exposure to UV radiation. Shade is a useful method of protecting the skin, but it only protects a person's eyes when he or she is facing a shaded area.**
- **The high cost and dark tinting of a pair of sunglasses are not indicators of an ability to provide greater protection against UV radiation. All Australian sunglasses must comply with Australian Standard 1067.**

Ultraviolet radiation and the electromagnetic spectrum

What is UV light?

Between 3 and 5% of the solar radiation that reaches the earth is UV, an invisible, high-energy radiation that occupies the segment of the electromagnetic spectrum between the visible light and x-ray regions (Figure A). UV radiation is commonly divided into three types:

- UV-A (320 to 400 nm), which causes tanning and is thought to contribute to skin cancer and ageing
- UV-B (290 to 320 nm), which causes sunburn and skin cancer
- UV-C (100 to 290 nm), which is extremely damaging to biological systems.

The ozone layer absorbs all UV-C and some UV-B radiation, and the radiation received on Earth contains much more UV-A than UV-B. Ozone depletion by chlorofluorocarbons is predicted to result in a modest increase in the incidence of skin cancer and eye related problems. This is a particular concern for residents in areas under depleted ozone, such as New Zealand and the deep south of Australia. Although UV-B radiation is more damaging than UV-A, the latter penetrates much further into the eye and may also cause injury.

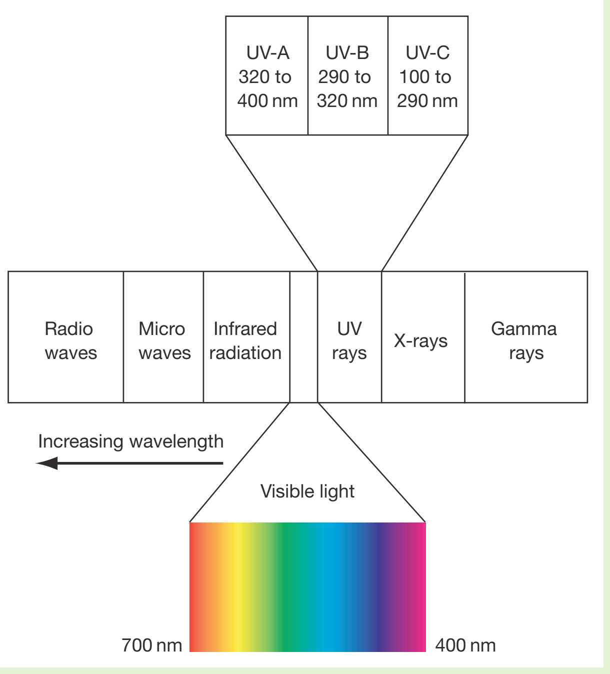

Figure A. The electromagnetic spectrum. Radiation received from the sun comprises infrared radiation, visible light, and a mixture of UV-A and UV-B radiation.

Biological effects

The acute effects of UV-A and UV-B radiation on the skin and eye include erythema, pigmentation, and injury to Langerhans cells and keratinocytes. These effects, which are short lived and reversible, result from release of histamine from mast cells and synthesis of arachidonic acid metabolites.

UV radiation also has long term biological effects, including enzyme inactivation, mutagenesis and inhibition of cell division, and high doses can lead to cell death. These mechanisms are responsible for the major health effects of UV radiation: premature ageing of the skin and ocular structures, and epithelial cancers. The ageing effects (e.g. wrinkling, solar elastosis, and pigmentation irregularities) are largely irreversible and result from increased expression of the elastin gene and increased synthesis of substances that degrade collagen. The carcinogenic effects of UV-B are attributed primarily to formation of pyrimidine dimers in DNA, which results in large transcription errors that can lead to cancer. UV-B also generates reactive oxygen species that contribute to cell damage.

exposure to UV radiation before the teenage years. They are very common in Australia and may be unilateral or bilateral (Figure 3).

Pterygia are most likely to be disorders of the limbal stem cells located at the junction of the conjunctiva and cornea. The pathology shows a fibrovascular pannus extending from the conjunctiva to invade Bowman's layer of the cornea (Figure 4); destruction of this layer may lead to corneal scarring and irritation. Occasionally, malignant change may occur in the head of a pterygium.

The definitive treatment of pterygia is surgical excision. Indications for removal include:

- active growth threatening vision
- chronic irritation
- decreased vision caused by disturbances of the tear film
- cosmesis (occasionally).

In the past, surgical results have been poor because of high rates of recurrence (between 30 and 90%, depending on the population). Use of adjunctive beta radiation has certainly shown a decreased incidence of recurrence; however, it

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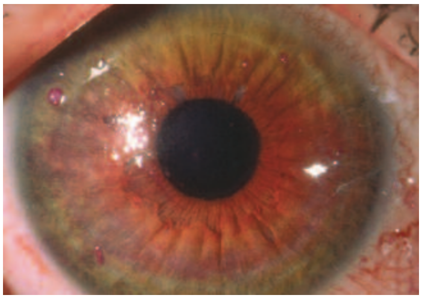


Figure 1. Solar keratitis in a cornea stained with rose bengal dye.

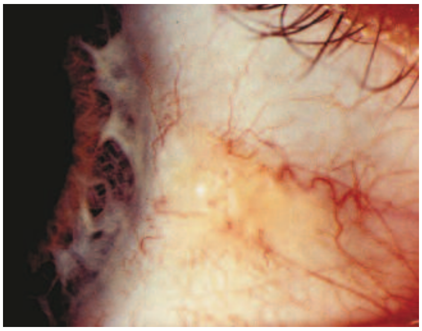


Figure 2a. Temporal pinguecula.

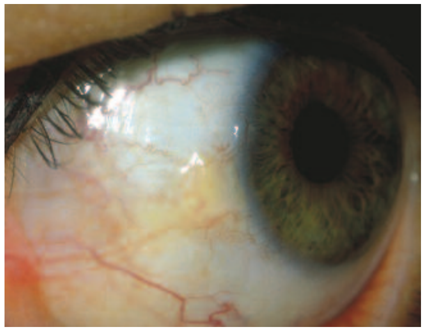


Figure 2b. Nasal pinguecula.

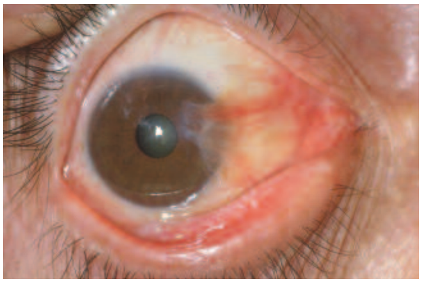


Figure 3. A nasal pterygium encroaching on the pupil.

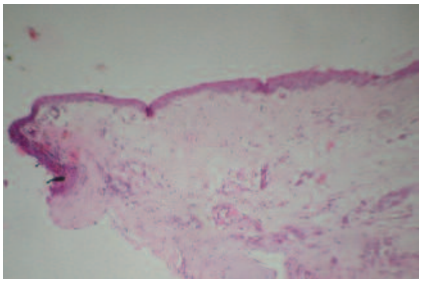


Figure 4. Fibrovascular pannus and destruction of Bowman's layer in pterygium.

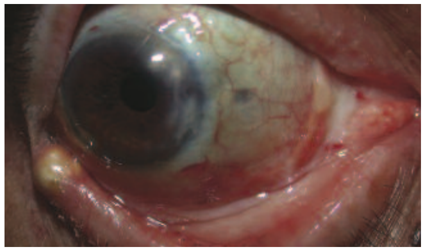
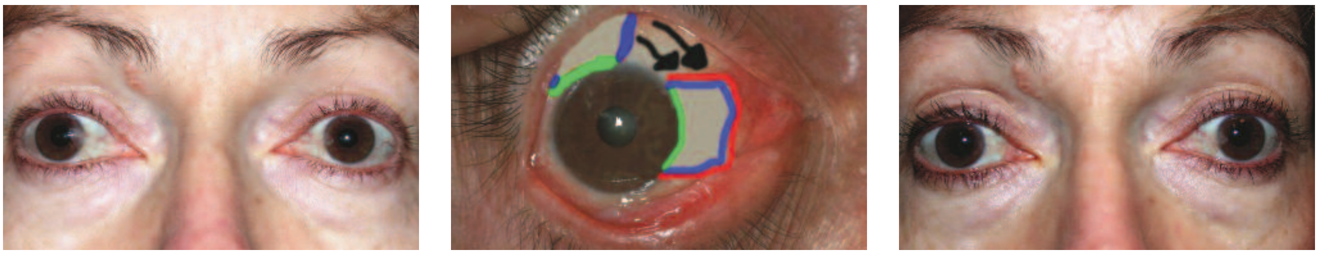


Figure 5. Scleral thinning, a complication resulting from use of beta radiation to prevent pterygium recurrence.



Figures 6a to c. a (left). A woman with bilateral pterygia. b (centre). After surgical removal of the right pterygium, autologous conjunctival grafting was performed. c (right). The woman three months after surgery (left eye yet to be operated on).

has been associated with long term problems due to an unknown safe dosage. These include conjunctival breakdown, scleral thinning (Figure 5), calcification, cataract formation, and an irritable dry eye resulting from damage to the conjunctival goblet cells. Endophthalmitis with loss of the eye may also occur. A safe dose of beta radiation has not yet been established.

The modern methods of pterygium removal involve either a free conjunctival graft or a sliding conjunctival flap, and is combined with careful removal of the subconjunctival tissue (Figures 6a to c). The fresh conjunctiva is usually obtained from the globe under the upper eyelid, which enables the defect to be filled with tissue that has been less exposed to UV radiation.

Droplet keratopathy

Spheroidal or climatic droplet keratopathy is a degenerative disorder caused by an irritative phenomenon due to UV exposure to the anterior corneal structures. The clinical appearance resembles that of an oil droplet occurring in both peripheral and (rarely) central locations (Figures 7a and b). Usually it is of clinical interest only and requires no treatment.

Salzmann's nodular degeneration

Like droplet keratopathy, Salzmann's nodular degeneration involves the anterior structures of the cornea (Figure 8). Large nodule-like changes occur that, because of their size and disturbance of the ocular tear film, can certainly interfere with vision. In addition, recurrent breakdowns of the overlying epithelium can occur and cause irritation.

If these nodules encroach on the visual axis, they can be removed by peeling away the scar tissue after debriding the surface epithelium. Alternatively, excimer laser can sometimes be used for removal.

Cataract

Cataract – particularly nasal cortical lens opacity – is one of the internal ocular degenerations that is related, in part, to exposure to UV radiation (Figure 9). Generally speaking, cataract is a multifactorial disorder, but there is certainly a relationship with UV radiation – around the world, it is more commonly seen in regions with higher levels of exposure.

Macular degeneration

There appears to be a link between macular degeneration and UV exposure over many years, although this association is controversial. There is also some recent evidence showing a relationship between macular degeneration and near-blue light (i.e. blue light wavelengths up to 450 nm).

Neoplasia

Conjunctival neoplasia is highly correlated with other skin neoplasias and is becoming more common in the Australian population (Figure 10). If left untreated, neoplastic changes in the conjunctival epithelium may become full thickness and break through into the underlying tissues, forming an invasive squamous cell carcinoma (Figure 11). This lesion may subsequently invade the internal eye and orbital structures, or even spread systemically in rare instances. Treatments include topical application of alfa-2b interferon (Intron A) or mitomycin C (Mitomycin C Kyowa), excision with cryotherapy, and possibly even eye wall reconstruction. Enucleation (removal of the eyeball) is necessary if the tumour has entered the eye and is not resectable. Exenteration (removal of the eye and orbital contents) may be required when orbital invasion has occurred.

Intraocular tumours such as choroidal melanomas may have a slightly increased prevalence in patients who are highly exposed to UV radiation. In general, other factors are involved in their development and growth.

Disorders affecting the skin of the eyelids are similar to those seen in other parts of the body. However, eyelid skin has a much greater propensity for changes caused by UV radiation because it has a relatively thin dermis. The incidence of epithelial dysplasia or full thickness intraepidermal carcinoma, basal cell carcinoma (Figure 12) and squamous cell carcinoma (Figure 13) is higher in this area than in other parts of the body.

Risk factors

Any factor that exposes an individual's eyes to additional sunlight will increase his or her risk of ocular damage caused by UV radiation. Those at greatest risk are people who, because of their occupation or recreational pursuits, are exposed to sunlight for lengthy periods – this is particularly true for Caucasians and

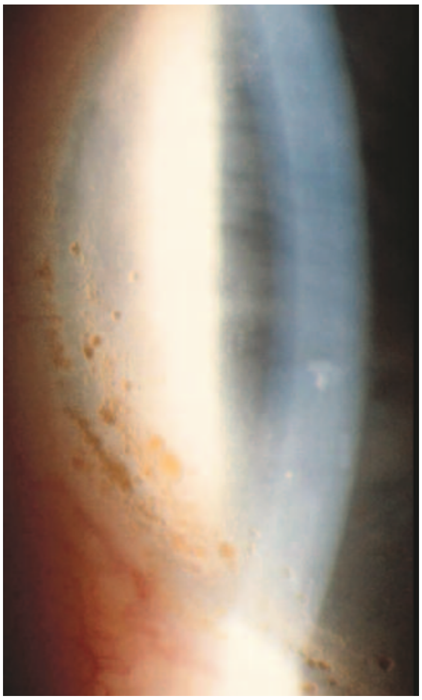


Figure 7a. Droplet keratopathy of the peripheral cornea.

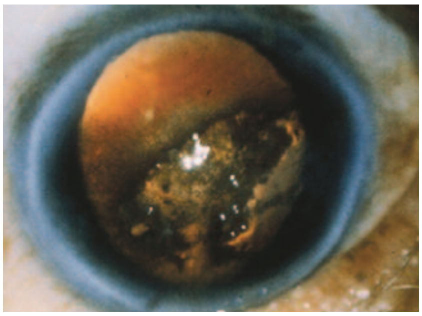


Figure 7b. Droplet keratopathy of the central cornea (rare).

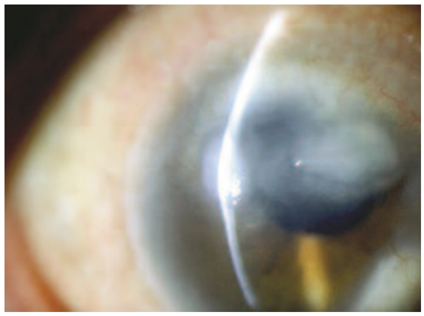


Figure 8. Salzmann's nodular corneal degeneration.

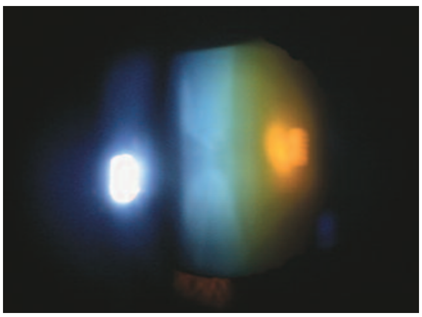


Figure 9. Nuclear sclerotic cataract.

Figure 10. Conjunctival dysplasia.

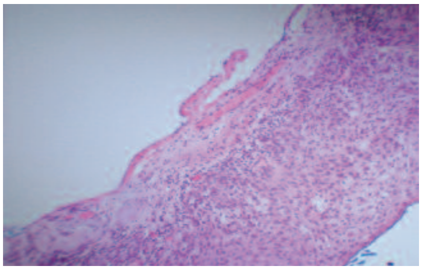


Figure 11. Full thickness dysplasia of the conjunctival epithelium.

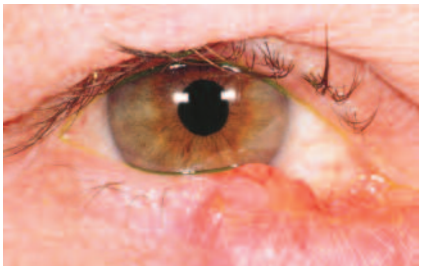


Figure 12. A basal cell carcinoma of the lower eyelid.

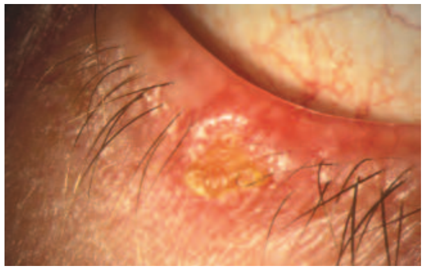


Figure 13. A squamous cell carcinoma of the lower eyelid.

especially those with a Celtic background. No-one is immune to the risk, but people who have Mediterranean or Aboriginal ancestry are much more resistant to the ocular effects of UV radiation.

UV levels are greatest between 10 a.m. and 3 p.m., which is when approximately 50% of daily UV radiation is received. Levels increase in summer and decrease with latitude, and are higher in those areas located under depleted ozone layer; therefore, residents of northern Australia are at greater risk.

Figure 14. Sunglasses with side shields offer good eye protection against UV radiation. However, they do block side vision and are not recommended for activities such as driving.

Dark skin (including tanned skin) is partly protective against UV exposure because melanin absorbs UV. People of dark skinned races have the same number of melanocytes in the skin and eye but produce more melanin.

Sun protection

Avoidance

Water, cloud and fog are not good UV filters. The radiation can penetrate 30 cm of clear water, so care must be taken when swimming or wading. Overcast skies do not offer any real protection – sunburn can occur on cloudy days as well as clear days. It is important to remember that it is solar UV radiation, not infrared radiation (i.e. heat), that is harmful. Shade is a useful method of protecting the skin, but it only protects a person's eyes when he or she is facing a shaded area.

Figures 15a and b. Goggles afford the best protection against exposure to reflected UV from snow. Note, however, that tinted lenses (a) and reflective coatings (b) do not provide additional UV protection.

Protective eyewear

The best UV protection is provided by UV absorbing sunglasses, particularly wraparound designs that limit the entry of peripheral rays. Sunglasses should be worn on sunny days – even clear plastic spectacle lenses absorb over 90% of incident UV rays. Sunglasses with occluding side shields are useful for stopping peripheral rays from reaching the eye (Figure 14); however, they do block side vision and are not recommended for activities such as driving.

Legally, all sunglasses sold in Australia must conform to Australian Standard 1067, which specifies the amount of UV protection that must be provided by the lenses. Sunglasses labelled 'general purpose' are suitable for most applications, whereas those labelled 'specific purpose' are more suitable for people who have a particularly high level of exposure to UV radiation (e.g. snow skiers). The effectiveness with which a pair of sunglasses absorbs UV radiation does not depend on cost or the colour of the lenses – the tint and density of the lens provide comfort from glare only.

Since UV radiation is reflected off surfaces (especially snow, water and sand), exposure is particularly high on the beach

The Royal Blind Foundation's annual 'Shades Day'

The Royal Blind Foundation of Queensland is campaigning to educate the public about the harmful effects of UV radiation on the eye and the importance of sunglasses to protect against these effects. This year, the Foundation's 'Shades Day' will be held on Wednesday, 29 October. For further information, phone (07) 3391 9191 or visit the website (www.rbf.org.au).

or while snow skiing or boating. UV-B radiation is concentrated by fresh snow, which reflects up to 80% of the radiation (sand reflects about 25% and water reflects about 2%). Polarising filters in sunglasses are effective in reducing glare but do not provide additional protection to a UV filter that blocks all wavelengths below 400 nm. Goggles afford the best protection against exposure to reflected UV from snow, but note that tinted lenses and reflective coatings do not increase the level of protection (Figures 15a and b).

Hats and clothing

The combination of wraparound UV absorbing sunglasses and a broad brimmed hat provides the best protection against ocular exposure to UV radiation – the hat or cap will block roughly 50% of UV radiation and limit the number of rays that may enter around the edges of the glasses. Studies assessing the amount of sun protection provided by various hat styles have shown that those with a brim of at least 7 cm not only protects the top of the head but also shades the face and neck – sites on which skin cancers commonly occur.

To best protect the skin, sunscreen as well as protective loose-fitting clothing should be used. The primary determinant of a fabric's ability to prevent exposure to UV radiation is the density of its weave, rather than the colour or type of fibre.

Conclusion

Despite increased media attention to the problems associated with UV exposure, the incidence of sun induced degenerative and neoplastic changes in the eye and surrounding structures is greater than ever before. This is due to a combination of factors, including the tropical climate experienced by much of Australia and an associated beach culture that promotes unprotected UV exposure from an early age, and the fact that our ageing population has a high proportion of susceptible people with Caucasian and particularly Celtic ancestry. Good ocular sun protection is of prime importance. MT

Further reading

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