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A Review on High Altitude Associated Ocular Problems

Preeti Yadav[1], Ajai Agrawal[2], Ramanuj Samanta[3], Anupam Singh[2], P. Sneha[1], Th. Samita Devi[1]

[1]Junior Resident, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India.
[2]Additional Professor, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India.
[3]Assistant Professor, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India.

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ABSTRACT

Background: Ocular problems at high altitude are an under-discussed area in Ophthalmology. Given the rarity of these disorders, there is less awareness and expertise in management among ophthalmologists. Altitude sickness usually occurs above 2,500 meters above mean sea level. The decrease in barometric pressure with increasing altitude, leads to fall in the partial pressure of oxygen from 159 mmHg at sea level to 18 mmHg at very high altitudes. This forms the basis of hypoxic problems. Besides, the effects of high solar ultraviolet radiation, cold and dry terrains are also to be considered. **Methods**: This review article focuses on ophthalmic ailments, their prevention and, management by paramedics, physicians and, fellow companions when timely specialist intervention is not possible. Apart from those conditions that primarily manifest at high altitudes, the knowledge of pre-existing ocular conditions and the effect of certain ocular surgeries at high altitude has also been addressed. **Results**: At high altitude, ophthalmic manifestations show an array of clinical pictures ranging from an abnormality in ocular motility, anterior and posterior segment involvement, as well as possible involvement of the visual cortex. With technical advances, not only do the inhabitants of high altitudes experience the effects of high altitude, but people involved in aviation, recreational sports, military deployment and, space exploration are also affected. Acute high-altitude morbidities are more common in non-acclimatized patients. **Conclusion**: The first responders at remote high-altitude locations play a crucial role. The awareness among the patients of their pre-existing ocular conditions before any ascent is vital.

Keywords: High altitude, Ocular problems, Ultraviolet rays.

INTRODUCTION

Ocular problems at high altitude are not a new arena, but a little less discussed upon. As technical advances are made in every field with the advent of millennium era, humans ascend to higher altitudes in aviation, for trekking and recreational sports, space exploration, and deployment of soldiers for strategic purposes. It has become imperative to understand the effects of altitude, low gas pressures, cold and dry terrains and high solar ultra violet (UV) radiation on the eye. Another issue which needs to be considered is pre-existing ophthalmologic conditions that may be exacerbated by high-altitude exposure.[1] Since such disorders are not common, only a minority of ophthalmologists are aware of the diagnosis and management. Altitude sickness typically occurs only above 2,500 meters above mean sea level (MSL), though some are affected at lower altitudes.[2]

The decrease in barometric pressure with increasing altitude is the basic cause of all the hypoxia related problems in high-altitude physiology because, as the barometric pressure decreases, the atmospheric oxygen partial pressure (pO_2) decreases proportionately, remaining at all times slightly less than 21 percent of the total barometric pressure; at sea level, pO_2 is about 159 mm Hg, but at 50,000 feet, pO_2 is only 18 mm Hg. This is based on the ideal gas law equation for pressure versus altitude (Barometric Formula), assuming a constant atmospheric temperature of 32 degrees Fahrenheit (0 degree Celsius), and 1 atmosphere pressure at sea level.

Name & Address of Corresponding Author
Dr. Ajai Agrawal
Additional Professor,
Department of Ophthalmology,
All India Institute of Medical Sciences,
Rishikesh, Uttarakhand, India.
Email: ajaiagrawal@rediffmail.com

This article focuses on the most common ocular ailments seen in the mountains, their diagnosis, management and triage in a remote field by paramedics, fellow mountaineers and physicians and also deals with the prevention and safe management of these problems, particularly when timely specialist help is not available.

There are both short-term and long-term effects of high altitude on the eyes. Short-term effects include high-altitude retinopathy, change in corneal thickness, and photo keratitis. The short-term effects are seen in the lowlanders ascending to high altitudes. The long-term effects are pterygium, cataract and dry eye syndrome. The long-term effects are generally noticed in the natives of high altitude.

There are also certain risk factors at high altitude which increases the magnitude of ocular problems and injuries and also pre-existing ocular morbidities. Some of these are ultraviolet light exposure (increased in snow and at high altitude), strong wind and small flying particles (e.g. ice, sand), high altitude and hypoxia, cold and dry conditions, activity during the night and in woods and bushes, contact lens use and previous history of eye problems (uveitis, herpetic keratitis, retinal detachment and ocular surgery).

Through this review article we will discuss the following ocular problems, their symptoms and management.

1. High-Altitude Retinopathy and Vascular occlusions
2. High UV Radiation and the Eyes
3. High Altitude and Dry Eye Syndrome
4. Contact Lens Use at High Altitude
5. Recurrent corneal erosions
6. Altitude and Keratorefractive Surgery
7. High-Altitude Cortical Blindness
8. Convergence, Accommodation, and Ocular Motility at High Altitude
9. Miscellaneous Clinical Conditions.

1. High-Altitude Retinopathy and Vascular occlusions

Hemorrhages, cotton wool spots, and disc edema that sometime occur at high altitude are known as high-altitude retinopathy (HAR). HAR was first described by Singh et al, who noted retinal vasculature changes in patients diagnosed with acute mountain sickness occurring between 11,000 ft. (3,353 m) and 18,000 ft.(5,486 m) above MSL.[3]In young subjects and physically active individuals, retinal haemorrhages are common due to more dilated vessels and systemic circulatory strain imposed on the retina during exercise in young patients.[4,5] Inadequate auto regulatory response of the retinal vascular system is thought to be responsible for HAR after chronic hypoxia.[6] Retinal blood flow increases by 128% after four days at 5,300 m above MSL.[7] This causes a clinically observed increase in diameter and tortuosity of the retinal blood vessels and optic disc hyperemia, which is considered to be a normal response to high altitude.[8,9]

Ophthalmoscopic features of this entity include retinal hemorrhages, dilated and tortuous retinal veins, optic disc swelling, anterior ischemic optic neuropathy, cotton wool spots, sub hyaloid hemorrhage, vitreous hemorrhage, and even rhegmatogenous retinal detachment. [10-17]

Retinal hemorrhages, intraretinal or preretinal are seen usually peripherally. In severe cases macular hemorrhage, vitreous hemorrhage, papilledema, and, rarely, cotton wool spots can be seen. Macular hemorrhage, or vitreous hemorrhage, may affect central vision. A statistically significant correlation ($p=0.0240$) between HAR and High Altitude Cerebral Edema (HACE) was found in a group of mountaineers during an expedition to Mount Everest.[4]

In addition to retinal haemorrhages and disc oedema, retinal vascular occlusions are also common in high altitude climbers.[18] Haemoconcentration at high altitude causes increased blood viscosity, increased coagulability and decreased oxygen transport capacity. Local stasis caused by impaired microcirculation and local high blood pressure peaks may cause capillary bursts.[11,18-21] Hypoxia due to pre-existing conditions such as diabetic retinopathy, central or branch retinal vein occlusion and chronic obstructive airway diseases causes increased expression of nitric oxide or vascular endothelial growth factor which lead to breakdown of inner blood retinal barrier and increased vascular permeability.[22,23]

Management Plan of High-Altitude Retinopathy

Asymptomatic hemorrhage, is normally self-limited and resolves within 7 to 14 days, and is not an indication for descent to lower altitudes. Patients with symptomatic HAR (especially impaired vision) should descend as soon as possible for further evaluation and treatment. Symptomatic HAR is treated as acute mountain sickness, with rest, oxygen, acetazolamide, and descent to a lower altitude.[24] It has also been seen that descent to lowlands leads to complete resolution of disc swelling.[25]

2. High UV Radiation Exposure and the Eyes

High solar ultra-violet (UV) radiation poses potential hazard. The amount of UV light increases with increasing altitude (at a rate of 4% for each 300-m ascent), low latitude, and in highly reflective environments. The reflection of UV light increases 2 times from the surface of water and 8 times from snow when compared with the reflection from a field of grass.[26] The natural defense mechanism of the eyes are brow ridges, eyebrows, and eyelashes, constriction of pupil and squinting of eyes. Protection offered by the natural defenses is limited during extreme conditions at high altitude.[27] There are both short- and long-term harmful effects of UV radiation on eyes. They involve both the ocular surface and the crystalline lens. Short-term effects of UV radiation exposure include Acute Keratitis and Snow Blindness.

Acute Keratitis and Snow Blindness

The sun's ultraviolet radiation (UVR) absorbed by the cornea , damage the corneal epithelium which is known as acute keratitis.[28] Acute keratitis is more common at high altitude because of the increased UVR and the presence of a highly reflective surface like snow.[29-31] Unprotected exposure to sun rays at high altitudes usually causes an inflammatory disorder of the cornea known as snow blindness. The main symptoms are severe pain, redness, foreign body sensation in the eyes, tearing, photophobia, and decreased visual acuity. Clinical signs to be looked in such cases are epiphora, blepharospasm, conjunctival chemosis, bilateral superficial punctate keratitis, and even corneal epithelial defects. Corneal epithelial defects can be seen with fluorescein strip and a pen torch (preferably with cobalt blue filter). There is a lag time of about 6–12 hours between UVR exposure and the onset of these symptoms in snow blindness and hence it is experienced by people going to mountains at night.[32] In individuals with light skin or with pre-existing ophthalmological conditions such as dry eye disease, keratoconus, and refractive surgery more severe signs can be seen.

Management Plan of Snow Blindness

Avoiding additional exposure to UV rays can be the first step towards preventing further damage. Relief from symptoms occurs within 24 to 72 hours, depending on the degree of UVR exposure.[33] Treatment include cool compresses, preservative-free lubricants, topical anti-inflammatory and cycloplegic medications, bandage contact lenses, ophthalmic antibiotic ointments and systemic analgesics.[34] Topical anaesthetic drops should not be used because they may delay corneal healing.[35] The mainstay of managing snow blindness is prevention. Appropriate UVR-filtering goggles or sunglasses with side shields should be worn.

As far as long-term harmful effects of UV radiations are concerned, it is seen mostly in the natives of the high-altitude region and include pterygium, climatic droplet keratopathy, and permanent endothelial morphological changes.[36] The prevalence of cataract at high altitudes is dependent on actual sunlight exposure.[37]

3. **High Altitude and Dry Eye Syndrome**

Dry eye syndrome is exacerbated in the dry, windy, and sun glare conditions seen at high altitudes.[38] Low humidity results in increased tear film evaporation. Increased tear evaporation can increase tear film osmolarity and may create dry eye disease independent of aqueous tear deficiency. Certain systemic drugs like alpha blockers, beta blockers, antidepressants, atropine-like agents, and systemic cold treatments such as ephedrine, pseudoephedrine, and antihistamines, which are commonly used in cold environments and at high altitudes decrease tear production.[1] Dry eye symptoms may vary from red eye, foreign body sensation, burning, photosensitivity, and blurred vision, depending on the degree of dryness.[39]

Management Plan of Dry Eye

The main stay of treatment is artificial tears and lubricating ointment. In cases with moderate to severe symptoms preservative-free artificial tears should be used.[1] Oral omega-3 fatty acids - increase tear secretion, decrease the amount of tear evaporation, and improve the symptoms of dry eye disease.[40] Decreased use of contact lens and use of fitted goggles or wrap-around sunglasses should be encouraged. Fitted goggles decrease tear evaporation and increase the humidity around the eyes.[28]

4. **Contact Lenses and High Altitudes**

Traveling may hinder proper handling, cleaning and storage of contact lenses.[1] Thus, their use is associated with an increased risk of corneal ulcers. Extended wear soft contact lens offers greater advantage of freedom from daily handling, comfort, and use. However, they are associated with greater risk of corneal ulcer than daily-wear soft contact lens. Disposable daily-wear soft contact lens is the preferable option in contact-lens-user mountaineers.[1]

Management Plan for Contact Lens use at High Altitudes

Painful eye in a soft contact lens-wearer mountaineer is a sign of corneal ulceration. Immediate discontinuation of contact lens along with instillation of antibiotic eye drop should be done. Referral to an ophthalmologist should also be considered. Mild discomfort is generally resolved with the more frequent use of lubricant. Overnight usage of extended-wear contact lenses should be avoided as it is associated with an increased risk of corneal infections.[1]

5. **Recurrent Corneal Erosion**

Recurrent corneal erosions are very common in people with previous corneal trauma, pre-existing epithelial basement membrane dystrophy, a history of photorefractive keratectomy, or LASIK. Symptoms include sudden onset of pain, tearing, and photophobia.

Management Plan of Recurrent Corneal Erosions

Frequent use of preservative-free artificial drops and antibiotic ointment. People with risk factors for this disorder should use topical lubricants as a preventive measure.

6. **Altitude and Keratorefractive Surgery**

Refractive surgeries are very common in an attempt to get freedom from glasses. Subjects with radial keratotomy (RK) to correct myopia may be at risk for visual deterioration at high altitudes.[41] Incisions of RK weaken the cornea and eventually lead to deformation during exposure to hypoxic conditions.[42] Progressive hyperopic shift was documented in eyes with RK, with measurements at sea level, 12,000 ft., and 17,000 ft.[43]

Management Plan of Refractive Surgery Disorder at High Altitudes

Such at risk subjects should travel with corrective spectacles. The visual changes correct with descent or prolonged stay at high altitude.[44]

7. **High-Altitude Cortical Blindness**

First described by Hackett et al in 1987, it is characterized by transient blindness in both eyes with intact pupillary reflexes.[45] Another form is amaurosis fugax in which there is monocular blindness along with relative pupillary afferent defect.[46] Both these conditions may be caused by a compromised blood supply to the visual cortex and the retina caused by vascular spasm of the central retinal artery in amaurosis fugax.[28]

Management Plan of High-Altitude Cortical Blindness

Oxygen inhalation or rebreathing carbon dioxide can improve the signs and symptoms of high-altitude cortical blindness by increasing cerebral blood flow. Also, descent can lead to the rapid recovery of visual function.[45]

8. **Convergence, Accommodation, and Ocular Motility at High Altitude**

Cranial nerve palsies, especially sixth nerve palsy, are associated with acute mountain sickness and high altitude cerebral edema.[47,48] Convergence insufficiency occurs due to a decrease in amplitude of convergence.[49]

Management plan of High-Altitude Ocular Dysmotility

When independent of high altitude cerebral edema symptoms, it is often a benign condition. The recovery from diplopia and muscle palsy may take several weeks to months.[50] Descent to low altitude may be the best treatment. [45,47]

9. **Miscellaneous Clinical Conditions**

Retinal Surgery with Intraocular Gas and High Altitude

Vitreoretinal surgical techniques frequently employ the introduction of a potentially expansile gas into the eye.[51] Travelers with intraocular gas are at risk of a clinically significant rise in IOP because the gas expands when exposed to reduced absolute pressure.[52] Unlike air, this gas can expand after being injected into the eye and take much longer to be resorbed back into circulation.[53]

Management Plan of Retinal Surgery with Intraocular Gas at High Altitudes

Due to the influence of increased IOP, the production of anterior chamber fluid, choroidal perfusion, and the prediction of the time of bubble resolution can vary considerably. A decision to travel to high altitudes should involve the treating surgeon.[51]

Diabetic Retinopathy and High Altitudes

High altitude traveling can be associated with retinal hemorrhage in diabetics. Blurring of vision can occur during hypoglycemic situations.[54]

Management Plan of Diabetic Retinopathy at High Altitudes

It is said that retinal hemorrhage in diabetics usually resolves after 1-2 weeks, even in cases when patients remain at high altitudes. Patients with diabetic retinopathy should finish the course of treatment prior to traveling.

Prevention and Protection

At high altitude, the eyes need protection from glare, UV rays, wind, and low humidity. A lightweight, closely fitting, wrap-around spectacle should be used. Spectacles should also provide clear vision without distortion. Sunglasses should not compromise color vision and contrast sensitivity. The desirable characteristics of sunglasses for use in mountains are 99%–100% UVR absorption, 5%–10% visible light transmittance, polycarbonate or CR-39 lens material, gray lens colour, robust frame design with side shields, or close wraparound design, stable and securely attached to the face and rigid carrying cases.[55]

CONCLUSION

High altitude exposes the eye to many adverse environmental factors and leads to ocular problems, particularly disorders related to dry and cold environments and hypoxic conditions. Ophthalmologists should be aware of prevention techniques and treatments for these ailments. Patients with past ocular problems or ocular surgery should consult an ophthalmologist before ascending to high altitudes. The role of first responders is very important at remote high-altitude locations and appropriate training should be provided for the same. Many of these ocular problems can be prevented by taking suitable protective measures. As human race treads new heights in aviation, recreational sports and strategic deployment of military forces, further research is required in this area for appropriate prevention and management guidelines.

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