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BRIEF REPORT

Ultraviolet Keratitis Among Mountaineers and Outdoor Recreationalists

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Objective.—Ultraviolet (UV) keratitis is a self-limited, inflammatory condition resulting in pain and temporary visual disturbance following acute UV radiation exposure. It may afflict mountaineers and other outdoor recreationalists because snow, water, and sand reflect a high percentage of UV radiation reaching the earth's surface. We examined the cases of UV keratitis that have occurred on National Outdoor Leadership School (NOLS) courses in order to better understand its epidemiology and to help prevent this affliction on wilderness expeditions.

Methods.—We retrospectively reviewed all cases of UV keratitis that occurred on NOLS courses from 1984–2009. Subject demographics and contributing factors were recorded and descriptive information reported.

Results.—Fifteen cases of UV keratitis occurred during the study period with an overall incidence of 0.06% in those exposed. All cases occurred in mountainous or snowy terrain except one case which occurred while boating on a river. Thirteen of the 15 (87%) cases occurred in participants who were not wearing sunglasses. Two cases (13%) occurred in participants who were wearing sunglasses without side shields. Ten cases (71%) occurred in sunny conditions, and 4 cases (29%) occurred in cloudy or low visibility conditions. In all cases, symptoms resolved within 36 hours after cessation of UV exposure.

Conclusion.—Appropriate eye protection, including adequate lenses with appropriate side shields, should be worn in mountain or water environments in order to prevent UV keratitis. This data supports the conventional conception of UV keratitis as a relatively mild and self-limited condition, if treated appropriately.

Key words: ultraviolet keratitis, snow blindness, mountaineering, river

Ultraviolet (UV) keratitis, also known as snow blindness or photokeratoconjunctivitis, is inflammation of the corneal epithelium and conjunctiva induced by exposure to UV radiation. Ultraviolet B and C (315–100 nm) are primarily responsible for this phenomenon.[1] The structures lying on the visual axis of the eye transmit incrementally smaller amounts of UV radiation from anterior to posterior so that, ultimately, $<1\%$ reaches the retina. Of these structures, the cornea absorbs the most UV radiation.

Ultraviolet keratitis is characterized by significant ocular pain and decreased visual acuity. A superficial punctate keratitis, usually bilateral, develops early and can lead to a large epithelial defect, severe pain, and excessive tearing. Full recovery with corneal reepithelialization usually occurs over 36 hours, and permanent damage is rare.

A literature search produced only a single article[2] that included epidemiological information regarding the prevalence of UV keratitis among outdoor recreationalists. We examined the cases of UV keratitis on National Outdoor Leadership School (NOLS) courses to learn more about the conditions and types of people who are affected on wilderness expeditions. Based on this information, we suggest strategies for prevention and provide management and treatment options.

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Methods

Criteria for reporting a medical incident on a NOLS course are described elsewhere.[3] We reviewed all cases

of UV keratitis that occurred on NOLS expeditions from September 1, 1984 through August 31, 2009. National Outdoor Leadership School was founded in 1965 and operates wilderness trips in mountain, river, and wilderness environments. National Outdoor Leadership School instructors made diagnoses presumptively based on symptoms of eye pain and photophobia following conditions conducive to UV keratitis. Objective measures such as slit lamp examination or fluorescein staining were not used because they are typically not available in the wilderness environment and not suitable for the medical training level of instructors. Information gathered about each case of UV keratitis included age, sex, occurrence date, specific activity at the time of the injury, geographic location of trip, role (student or instructor), any objective and subjective factors contributing to the injury, and whether the participant required evacuation or hospitalization. Information was recorded by instructors while on the course and reported to course directors who entered information into the database. Results are presented with descriptive information and were performed with SPSS v 16 (SPSS, Inc, Chicago, IL). The study was reviewed and approved by the University of Utah Institutional Review Board.

Results

Fifteen cases of UV keratitis were reported during the study period. The incidence was 0.06% in those who were exposed to conditions conducive to snow blindness (total of 23 257 participants travelling on snow and/or water) and 0.02% for all participants during the study period (total of 65 141 participants). One case of UV keratitis was reported in 1989, 3 were reported in 1995, zero in 1998, 1999, 2000, 2002, 2004, 2005, 2009, and either 1 or 2 cases in the remaining years. Afflicted subjects had a mean age of 23.7 years (SD $\pm$ 4.1, range 19–31) and 40% were male. All cases occurred in mountainous or snowy terrain except one case which occurred while boating on a river.

Thirteen of the 15 (87%) cases occurred in participants who were not wearing sunglasses. Reasons given for not wearing sunglasses included: overcast or "not bright enough" conditions (2 cases), glasses were fogging (2 cases), lost or forgot glasses but did not inform instructors (2 cases), had no prescription sunglasses (1 case), and removed because of spindrift (1 case).

Two cases (14%) occurred in participants who were wearing sunglasses without side shields or wrap-around protection. Both of these occurred on glacier terrain. Ten of the 15 cases (71%) occurred in sunny conditions and 4 cases occurred in cloudy or low visibility "whiteout" conditions (conditions not documented in one case). National Outdoor Leadership School instructors were affected in 3 cases (20%). On cloudy days, both students and staff members were affected, whereas only students were affected on days with bright sun conditions.

The onset of symptoms in all cases occurred within 24 hours of exposure. Symptoms resolved within 36 hours when the afflicted person avoided further UV exposure by donning sunglasses (if not previously worn) or seeking shelter in a dark place. No evacuations or hospitalizations were required, and no other personal injuries, complications, or any negative impact on the trip were reported because of the condition.

Discussion

The UV keratitis cases that occurred during NOLS courses illustrate the classic presentation of the condition. A number of interesting cases can be instructive for wilderness medical professionals and individuals who participate in activities that put them at risk for UV keratitis. Those participating in wilderness expeditions should be aware of the environments that may cause UV keratitis and the medical aspects of preventing and treating the affliction.

The eye possesses internal and external mechanisms to protect itself from UV radiation. The eyelids and brow block some of the overhead light from reaching the eye, so UV radiation exposure that reaches the eye is mostly from light reflected up off the ground and from light traveling at a low angle or from the horizon. Squinting is an involuntary response to intense light, but it still blocks proportionally more overhead light than reflected light and, therefore, does not greatly diminish UV radiation exposure.[4]

It has been estimated that an exposure of only 2 hours of UV radiation reflected from snow is enough to cause UV keratitis.[5] Snow-covered ground and the "whiteout" conditions caused by spindrift increase the proportion of visible light and UV radiation that are reflected toward the eye. Snow and water may reflect up to 88% of UVB radiation that reaches the ground.[4]

Certain environmental factors affect UV exposure and are of particular interest to mountaineers and other outdoor recreationalists. Although the ozone layer absorbs most UV radiation directed at the earth in absolute terms, UV radiation reaching the earth's surface increases with altitude at a rate of approximately 4% per 1000 feet of elevation gain because of decreased atmospheric absorption.[6] Also, when the sun is low in the sky due to season or time of day, the path through the atmosphere is relatively longer, which allows for increased absorption, and less UV radiation reaches the earth's surface. Conversely, when the sun is high in the sky, more UV

radiation is transmitted through the atmosphere. For this reason, more UV radiation reaches the earth as one nears the equator. During the winter months, the sun remains lower in the sky than during the summer. Although this does decrease the total amount of UV radiation that reaches the earth, it is travelling at a low angle that enables it to reach the eye for more hours out of each day.[7]

Prevention strategies include wearing a hat to block exposure from above and wearing sunglasses to block low-angle and reflected UV radiation. Intensity of light, or luminance, measures approximately 350 to 2000 candelas per square meter (cd/m^2) in conditions that are comfortable to the eye.[8] Normal sunglasses transmit 15% to 25% visible light and are adequate for these environments. On snow during a bright day, however, luminance may be 15 000 to 30 000 cd/m^2, requiring sunglasses that transmit less light (for example only 5% to 10% of visible light).[9] Dark, large-lens sunglasses that fit close to the face with side shields and wrap-around protection should be adequate for these conditions. Goggles may also be an important piece of equipment in the mountains, particularly in high wind environments. Wearing sunglasses without side shields allows light to enter around the sunglass frames. This light can then reflect off the nose, cheeks, and posterior surface of the sunglass lens, potentially increasing the amount that reaches the eye.[4] In one NOLS case, the participant's UV radiation exposure occurred after only 4 hours of glacier travel while wearing sunglasses without side shields. In certain specific conditions, sunglasses without side shields may not significantly decrease (and may actually increase) UV exposure and do not protect against snow blindness. Sunglasses should be selected specifically for the conditions that will be encountered and for their UV-filtering properties.[9]

The reasons that subjects did not wear sunglasses can be divided into 2 categories: environmental and logistical. Environmental reasons for not wearing sunglasses were due to the participant's perceived intensity of light. Presumably, participants in some cases felt that their vision was hindered by sunglasses in cloudy conditions. In 2 cases, the weather conditions were overcast and cloudy. In 2 other cases, spindrift caused "whiteout" conditions. In one case, the participant was canoeing on a river and likely did not perceive a threatening condition. These cases reinforce the need to wear sunglasses when traveling on reflective surfaces such as water or snow, even if the conditions are not bright. Staff should be aware of the environment, whether sunny or cloudy, and their students' reactions to changing conditions. Staff should also ensure that they themselves are taking precautionary measures in cloudy conditions. This awareness may help prevent future cases of UV keratitis.

Beyond environmental reasons for not wearing sunglasses, the most common logistical contributors to not wearing sunglasses were weather, fogging of the glasses, and lost equipment. Sunglasses with side shields or wrap-around protection should be accessible. A means of cleaning, such as a bandana or cleaning cloth, should be readily available. A spare pair of sunglasses should be carried if traveling on terrain where UV keratitis could occur.

If sunglasses are lost, improvised eye protection can be constructed from cardboard with small holes punched to allow vision. Side shields can also be made from cardboard, paper, or first aid tape. Inuits and other natives living in bright snowy environments have carved caribou and other animal bone to fashion eye protection with slits in the center. These makeshift devices filter a majority of light while still allowing limited vision.

In all NOLS cases, the time interval from exposure to the onset of symptoms was less than 24 hours. As mentioned previously, the onset of symptoms is typically within 12 hours of exposure. The duration of symptoms was less than 36 hours in all NOLS cases, except one in which the participant was re-exposed to sunlight. Although UV keratitis is a relatively minor injury that resolves in a relatively brief period of time, the severe discomfort may be debilitating as well as potentially dangerous in the wilderness setting because it may limit an individual's sight and mobility for 1 to 2 days.

Individuals with UV keratitis may not be able to contribute to team expedition responsibilities, such as ferrying loads to an advanced camp, thereby causing the other team members to carry a greater burden and to become more fatigued. Worse yet, if circumstances require the team to descend emergently, the individual will require assistance, therefore slowing progress and putting other team members at risk. National Outdoor Leadership School trips usually consist of large groups (10–15 members), which minimizes the burden of accommodating a team member with UV keratitis. However, smaller expeditions may find themselves in a hazardous situation if one of the members becomes afflicted. On NOLS courses, no significant complications for the individual or the team were reported, although one individual did require assistance on a mountain descent.

The epidemiology of UV keratitis has been reported only rarely. The prevention and management of UV keratitis does not involve the level of complex physiology as other entities such as acute mountain sickness. Its incidence deserves study, however, considering the potential limitations on individual or expedition health if one is afflicted. Perhaps UV keratitis is rare because it is

easily prevented. In Basnyat's case series of 155 trekkers and porters in the Nepal Himalaya,[2] four experienced UV keratitis. Ultraviolet keratitis only affected the hired porters. This group was the least likely to have appropriate clothing and eye protection. More studies examining different groups will help us to understand better how to prevent and treat UV keratitis.

If one becomes afflicted with UV keratitis, the primary treatment strategy is to avoid further UV exposure by wearing sunglasses and resting in a dark place, such as a tent. With this treatment, symptoms typically resolve within 48 hours with no permanent effects.[5,10] In emergency situations, short-term administration of topical anesthetic can be useful in helping a stricken climber descend to safety.[1] The most important refractive interface for vision is the air-to-tear film. Vision is typically very blurred as a result of the constant tearing induced by the trauma to the cornea. Moreover, the pain of blinking over the exposed raw corneal surface makes it difficult to open the eyes. A topical anesthetic will relieve the pain and stop tearing, which will allow a safer descent over technical climbing terrain. However, topical anesthetics delay, and can even prevent, epithelial healing. Thus, topical anesthetics should only be used in situations requiring the afflicted person to assist in their own evacuation. Otherwise, victims should rest with their eyes closed until symptoms resolve.

Additionally, nonsteroidal anti-inflammatory eye drops and oral acetaminophen or narcotic analgesics can be used to alleviate discomfort. Corneal ulceration is possible with significant exposures. Antibiotic eye drops should be used for moderate to severe cases to help protect against infection, but these are not needed in mild cases and may not be in a typical first aid kit. After UV keratitis has resolved, sunglasses with sun shields should be worn during the daytime to prevent recurrence.

Those who participate in wilderness expeditions should be aware of the prevention, pathology, and treatment of UV keratitis. The affliction can be readily prevented if one prepares properly and respects conditions that may precipitate it. Ultraviolet keratitis is usually a mild condition that can be properly managed; however, it may be incapacitating if demanding activity is required. Both experienced and inexperienced wilderness travelers are susceptible and should be attentive to UV keratitis.

Limitations

Specific details are limited by the retrospective nature of the study. Descriptions of incidents are typically recorded by instructors who have varying levels of medical training and who diagnosed UV keratitis presumptively based on symptoms. In 1994, a reporting category of "snow blindness" was added to the NOLS incident database. Therefore, underreporting of the condition may have occurred during the period of 1984–1993.

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