Photokeratitis and UV-Radiation Burns Associated With Damaged Metal Halide Lamps

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Background: Damaged metal halide lamps are known to cause outbreaks of photokeratitis and UV-radiation burns among children and adults, which has prompted the Food and Drug Administration, Rockville, Md, to publish consumer recommendations to prevent such injuries. We investigated 3 outbreaks of photokeratitis and UV-radiation burns in gymnasiums associated with failure to heed these recommendations.

Objective: To determine the cause of the outbreaks and promote interventions to prevent further injuries.

Design and Setting: A cohort study of persons exposed to damaged metal halide lamps during the index outbreak in a community gymnasium and a descriptive epidemiologic study of 2 subsequently identified outbreaks in other gymnasiums.

Participants: A total of 273 persons potentially exposed during events in 3 gymnasiums.

Main Outcome Measure: Photokeratitis with onset within 12 hours of the event. The intensity of UV radiation was measured, and an occupational exposure standard applied.

Results: Investigation of the index outbreak identified 18 (approximately 3%) persons who met our case definition for photokeratitis. The median incubation period was 7 hours, and health care visits were reported by 11 persons (61%). Of the 18 patients, 17 (94%) were seated in the back of the gymnasium. Among 37 persons sitting in this high-risk area, the attack rate was 46%. Only 1 (9%) of 11 persons wearing glasses or contact lenses developed photokeratitis (relative risk, 0.15; \(P = .01\)). The safe occupational exposure limit in the high-risk area developed photokeratitis (relative risk, 0.15; \(P = .01\)). The safe occupational exposure limit in the high-risk area was 10 to 15 minutes, but exposures of 1 to 3 hours were reported. Prevention recommendations had not been instituted at any of the 3 facilities.

Conclusions: Injuries from metal halide lamps are avoidable, but prevention recommendations may not be widely observed. All facilities using metal halide lamps in areas where children may be exposed should follow the Food and Drug Administration recommendations; amending the National Electric Code may be warranted.


Photokeratitis is damage to the corneal epithelium from UV radiation (UVR) from natural or artificial sources. Well-recognized examples include snow blindness and welders’ arc burns. Peak symptoms typically occur 6 to 12 hours after exposure and include photophobia, foreign-body sensation, tearing, and blurry vision. Characteristic clinical findings include conjunctival injection and punctuate erosions of the corneal epithelium with an intrapalpebral distribution. Another characteristic finding is UVR burns of the exposed skin around the eyes. Photokeratitis usually resolves spontaneously in 24 to 48 hours with symptomatic treatment. Clusters of photokeratitis among children and adults associated with damaged mercury-vapor or metal halide lamps, which are commonly used to light gymnasiums, have been reported.

Metal halide lamps contain an inner arc tube, analogous to a welder’s arc, that emits intense UVR along with visible light (Figure 1). The UVR is normally attenuated by the outer glass envelope so that UVR exposure is negligible. However, a UVR hazard can occur when the outer glass envelope is broken, as by a flying object, and the inner arc tube continues to function and emit UVR that is no longer attenuated by the glass envelope. Nevertheless, injuries from metal halide lamps are preventable. Because they are radiation-emitting devices, the Food and Drug Administration (FDA), Rockville, Md, has issued consumer recommendations for safe operation, which must be displayed on lamp packaging. However, nonadherence to these prevention measures may be widespread.

In February 2003, a local health department notified the Tennessee Department of Health, Nashville, of 8 persons...
who reported severe eye symptoms after attending a fund-raising event in a nonprofit youth center gymnasium. An epidemiologic and environmental investigation was performed. As a result of publicity from this outbreak, 2 other outbreaks of photokeratitis were reported and investigated. One occurred 2 weeks later at a high school that had hosted a 3-day wrestling tournament in its gymnasium; the other was among volleyball players at a municipal gymnasium. This article describes the findings from these 3 outbreak investigations.

**METHODS**

We performed a cohort study of persons who attended the fund-raising event at the youth center gymnasium. A case was defined as acute eye symptoms (including ≥3 of the following: conjunctival injection, burning or itching, photophobia, foreign-body sensation, tearing, blurry vision, periorbital edema, and skin erythema) with onset within 12 hours of the event occurring in persons who attended it and who had no preexisting eye symptoms. Case finding consisted of identifying and calling at least 1 representative from each table and all persons in the area where most injuries occurred (defined as the high-risk area). A questionnaire was administered to all persons contacted to determine the location of their table, whether they had any of the above symptoms, and whether they wore eyeglasses or contact lenses with UVR protection. Consent was obtained, and the medical records of those who sought medical attention were reviewed.

To determine the dose of UVR to which persons were exposed, we measured the effective irradiance, or biological effectiveness of UVR, from a damaged metal halide lamp in the high school gymnasium. The outer glass envelope, which normally attenuates UVR, was broken and completely missing. Evaluation of effective irradiance could not be performed at the youth center gymnasium because the damaged lamp was unavailable. However, all of the gymnasiums had high-bay lighting fixtures with aluminum reflectors and used 400-W, R-type metal halide lamps, which were 6.2 m above the floor. Therefore, data collected at the high school gymnasium were considered to be representative of effective irradiance during the index outbreak. Measurements were taken with a radiometer/photometer (IL model 1400A; International Light Inc; Newburyport, Mass), which spectrally matches the UVR hazard bandwidth (190-400 nm) to generate effective irradiance in microwatts per centimeter squared. Measurements were taken at 1.3 m above the floor (to simulate the height of a seated person’s head) at a point directly below the damaged lamp (center point) and at 1-m intervals off the center point. Measurements were taken with the radiometer probe oriented horizontally (0°) toward the center point to simulate line of sight. To estimate the hazard to children and adults, effective irradiance was converted to occupational exposure limits by using a table published by the American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.14 Exposure time required to reach minimal erythemal dose (MED) was calculated by using the formula 5.83 µW/cm²=1 MED/h. Statistical analyses were performed using χ² tests calculated with Epi Info 2002 software (Centers for Disease Control and Prevention, Atlanta, Ga).16

**RESULTS**

An estimated 600 persons attended the evening fund-raising event, which lasted 2 to 3 hours (6-9 PM), in the youth center gymnasium. Attendees were seated at tables arranged throughout the gymnasium for a catered meal and presentations by several speakers, including a nationally recognized sports figure. Of the approximately 600 persons who attended, we contacted 119 (approximately 20%), including at least 1 person from each of the 52 prepaid tables and 10 general admission tables along the back of the gymnasium. All persons contacted completed the questionnaire.

Eighteen persons (approximately 3%) met our case definition for photokeratitis (Figure 2). Among the 18 patients, 13 (72%) also had UVR burns on their faces, most commonly on the forehead or eyelids. In addition, we identified 2 persons who were wearing UVR protective eyeglasses who had UVR burns on their faces without eye symptoms. The duration of exposure for most persons with photokeratitis (94%) was 2 to 3 hours; 1 person was present for only 1 hour. The median incubation period was 7 hours (range, 4-11 hours). Health care visits were reported by 11 persons (61%); 4 were awakened from sleep and visited an emergency depart-
The person who developed photokeratitis despite wearing glasses with UVR protection was affected only in the corner of his left eye in an area not covered by the glasses.

The gymnasium was lit by 20 high-bay lighting fixtures with metal halide lamps and aluminum reflectors. When the investigators arrived at the gymnasium 2 days later, no damaged lamps (ie, broken outer glass envelopes) were identified. However, an employee verified that a lamp with a broken outer glass envelope had been replaced since the event. This lamp was located above and in the line of sight of persons at the 5 tables in the high-risk area as they looked toward the stage. The aluminum reflectors of several lighting fixtures throughout the gymnasium were dented or tilted, indicating possible damage from flying objects. The 5 high-risk tables were estimated to have been 3 to 6 m off center from a point on the floor directly below the implicated lamp.

The environmental investigation demonstrated that the peak effective irradiance, which is a measure of the biological effectiveness of UVR, was 5.2 µW/cm² at 4.5 m off center with the sensor in a horizontal position (Figure 4). When an occupational standard is applied, that effective irradiance corresponds to an occupational exposure limit of 5 to 10 minutes according to the American Conference of Governmental Industrial Hygienists. The effective irradiance at 6 m off center was 3.8 µW/cm², which corresponds to an occupational exposure limit of 10 to 15 minutes. When the effective irradiance measured during the environmental investigation was converted to MED, it was determined that MED would be reached by 0.7 hour at 3 m and 2.1 hours at 6 m in a person with fair skin.

As a result of publicity from this outbreak, we were notified of and investigated 2 other outbreaks of photokeratitis. The first occurred 2 weeks later at a high school that hosted a 3-day wrestling tournament in its gymnasium. It was noted that 1 of the metal halide lamps in the gymnasium was damaged. We interviewed 149 (about...
We investigated 3 outbreaks of photokeratitis and UVR burns associated with exposure to UVR from damaged metal halide lamps in gymnasiums used primarily by children. The intensity of the UVR measured during the environmental investigation of the second outbreak was such that the occupational exposure limit would have been 10 to 15 minutes in the high-risk area, which is the same limit as during the index outbreak at the youth center; the actual exposure times were 2 to 3 hours. The attack rate in the index outbreak was 46% for photokeratitis and 41% for UVR burns for persons in the high-risk area. Our cohort study demonstrated that UVR-attenuating eyeglasses or contact lenses were protective against photokeratitis.

Photokeratitis from acute UVR exposure during these outbreaks produced severe eye symptoms that resulted in emergency department and ophthalmologist visits and missed work. Although its exact role in the development of cataracts is debated, animal studies have demonstrated cataractogenesis after acute laboratory exposure to UVR. In addition, an association between lifetime exposure times of up to 12 hours. Spectators were disproportionately affected. Among the 46 persons with photokeratitis, 24 (52%) also reported UVR burns to the face. The most common eye symptoms were conjunctival injection, burning, and photophobia, and 24 (52%) persons sought medical care.

Another outbreak occurred among volleyball players at a municipal gymnasium. We interviewed 5 persons who played together who had symptoms consistent with photokeratitis or UVR burns on 3 occasions during a period of 3 months after playing volleyball at the gymnasium. The duration of exposure on each occasion was estimated to have been 1 to 3 hours. An investigation initiated after complaints by patrons revealed a damaged metal halide lamp over the volleyball court.

COMMENT

We investigated 3 outbreaks of photokeratitis and UVR burns associated with exposure to UVR from damaged metal halide lamps in gymnasiums used primarily by children. The intensity of the UVR measured during the environmental investigation of the second outbreak was such that the occupational exposure limit would have been 10 to 15 minutes in the high-risk area, which is the same limit as during the index outbreak at the youth center; the actual exposure times were 2 to 3 hours. The attack rate in the index outbreak was 46% for photokeratitis and 41% for UVR burns for persons in the high-risk area. Our cohort study demonstrated that UVR-attenuating eyeglasses or contact lenses were protective against photokeratitis.

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What This Study Adds

Several outbreaks of photokeratitis and sunburn associated with damaged metal halide lamps were reported in the late 1970s, and as a result, the FDA required warning labels on these lamps. However, our investigation demonstrates that outbreaks of photokeratitis and rash continue to occur and may be more common than previously appreciated. Because damaged metal halide lamps are often recognized only after they are linked to a health complaint, increased awareness of this hazard is necessary to correctly diagnosis this preventable cause of keratitis and rash in school-aged children, which can be mistaken as an infectious process. The FDA prevention recommendations are infrequently implemented in facilities used by children, which has prompted the National Electrical Manufacturers Association to petition that these recommendations be reflected in the National Electric Code.

halide lamps that do not self-extinguish are commonly used in open fixtures in gymnasiums where they are at risk for damage by flying objects. Once damage has occurred, if the broken glass is not reported to the proper person, the problem can be difficult to detect because lamps may continue to function normally. Disincentives may exist for children to report damaged lamps, such as disciplinary action. Furthermore, many facilities do not have the proper equipment on site, such as a mechanical lift, to reach the 6-m-high fixtures to change a damaged lamp. Even after a damaged lamp is discovered, it might not be recognized as a health hazard and therefore might not be replaced until it fails, is replaced during scheduled maintenance, or causes injuries.

Injuries and outbreaks related to metal halide lamps are likely underreported, especially in children. Since the problem is not well recognized, when sporadic injuries occur, the possibility of exposure to a damaged metal halide lamp may not be as apparent as when an outbreak occurs. Sporadic injuries or small clusters might be attributed to infectious causes of conjunctivitis or rash illness in children.

To prevent these injuries, the FDA recommends that either enclosed fixtures or self-extinguishing lamps be used in areas where persons may be exposed for prolonged periods. Enclosed fixtures would protect the lamp from damage and, in the event of damage, the glass or plastic lens would attenuate the UVR. Self-extinguishing lamps are designed to stop functioning within 15 minutes if the outer glass envelope is damaged and may be used in open fixtures, but such lamps are more expensive than those that do not self-extinguish and so are not routinely used or widely available. The National Electrical Manufacturers Association, Rosslyn, Va, has also recently published recommendations for schools.

The fact that outbreaks associated with metal halide and mercury-vapor lamps continue to occur indicates a failure of the current level of recommendations. Ultimately, a change to the National Electric Code might be required and has been proposed by the National Elec-
A trihalde Manufacturers Association. All facilities that use metal halide lamps where persons may be exposed for extended periods of time should follow the FDA or National Electrical Manufacturers Association recommendations.12,19 Injuries or outbreaks associated with metal halide lamps should be reported to the state or local health department and the FDA (Center for Devices and Radiological Health, Office of Compliance, MS HFZ-342, 2098 Gaither Rd, Rockville, MD 20850, telephone: 301-594-4654).

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REFERENCES

11. Mercury vapor lamps may be dangerous, says the FDA. JAMA. 1979;242:1837.