

## Occupational risk from ultraviolet germicidal irradiation (UVGI) lamps

E. A. Talbot,\* P. Jensen,† H. J. Moffat,‡ C. D. Wells\*

\* Division of TB Elimination, NCHSTP, Centers for Disease, Control and Prevention, Atlanta, Georgia, † National Institute of Occupational Health and Safety, Morgantown, West Virginia, USA; ‡ Ministry of Health, Gaborone, Botswana

### SUMMARY

The recommended role of ultraviolet germicidal irradiation (UVGI) is to reduce the risk of tuberculosis (TB) transmission in health care facilities. However, excess exposure may result in dermatosis and photokeratitis. In one hospital setting in Botswana, two nurses and one housekeeper complained of eye discomfort, 'like sand in the eyes', after working in an administrative office. The following day, one employee noted facial skin peeling. All symptoms resolved over 2-4 days without sequelae. Six weeks later, the syndrome recurred for all three employees. A workplace investigation revealed that the office had been converted from a hospital sputum induction room, and that an unshielded 36-W UVGI lamp was still installed and operational. The on/off switch for the UVGI lamp was immediately adjacent to the fluores-

cent bulb on/off switch, and did not have a locking mechanism. The US National Institute for Occupational Safety and Health recommends that exposure to UVGI (254 nm) be less than 6000  $\mu\text{J}/\text{cm}^2$  (6000  $\mu\text{W}\cong\text{sec}/\text{cm}^2$ ) over a daily 8-hour period on unprotected skin or eyes. In the office, UVGI measurements at eye level and looking directly at the UVGI lamp ranged from a low of 20.0  $\mu\text{W}\cong\text{sec}/\text{cm}^2$  when seated to a high of 49.9  $\mu\text{W}\cong\text{sec}/\text{cm}^2$  when standing. These irradiance levels result in allowable exposure times of 300 and 120 seconds, respectively, and are the most likely cause of the clinical syndrome described.

**KEY WORDS:** tuberculosis; ultraviolet germicidal irradiation; UVGI

IN THE 1940s and 1950s, Wells et al. described the efficacy of ultraviolet germicidal irradiation (UVGI) for interrupting transmission of airborne infections.<sup>1</sup> Although some of Wells' research could not be duplicated, it led to many anecdotal reports of the efficacy of UVGI in preventing the spread of tuberculosis (TB).<sup>2</sup> In order for UVGI to be effective, the aerosols containing *Mycobacterium tuberculosis* (droplet nuclei) must remain airborne and must obtain a sufficient UVGI dose to be killed or inactivated. As stated by Riley and Nardell, droplet nuclei have negligible settling velocity and will be dispersed with air currents.<sup>2</sup> Because of this, both the World Health Organization and the Centers for Disease Control and Prevention (CDC) include a role for UVGI in their guidelines to reduce airborne TB transmission in health care facilities.<sup>3,4</sup> However, there are also risks associated with its use: excess exposure may result in dermatosis and photokeratitis.<sup>5,6</sup> Therefore, the US National Institute for Occupational Safety and Health recommends that exposure to UVGI (254 nm) be less than 6000  $\mu\text{J}/\text{cm}^2$  (6000  $\mu\text{W}\cong\text{sec}/\text{cm}^2$ ) on unprotected skin or eyes over a daily 8-hour period.<sup>7</sup> (This recommendation does not apply to photosensi-

tive individuals or persons concomitantly exposed to systemic or topical photosensitizing agents.)

### CASE REPORT

In a hospital in Botswana, a research nurse called in sick from work with 'an eye infection'. A second nurse, who was assigned to the same office, also called in sick on the same day, with complaints of eye burning and pain, and facial swelling. She sought medical attention in an out-patient setting. The housekeeper who had cleaned the office the day before reported to work, but complained of the sensation of 'sand in her eyes'. A friend who visited them at this office for a few minutes had similar but milder symptoms. Questioning the three employees led to the discovery that the day before they had worked together for approximately 2 hours to clean the office, which required moving bottles of chemicals, including glutaraldehyde and formalin. The employees' symptoms were presumed to be related to the chemicals, which were promptly removed. Their symptoms resolved over approximately 48 hours.

Correspondence to: Elizabeth A Talbot MD, Associate Director TB-HIV Research, The BOTUSA Project, 2170 Gaborone Place, Dulles, VA 20189-2170, USA. Tel: (+1) 267-301-696. Fax: (+1) 267-373-117. e-mail: edt7@cdc.gov

Article submitted 28 November 2001. Final version accepted 22 April 2002.

Over the following 6 weeks, the two nurses continued to use the office, and the housekeeper came in weekly to clean it, without incident. However, one day, all three staff developed recurrent symptoms 2–8 hours after leaving the office. They complained of burning, watery eyes, photophobia, and facial edema. One reported to the emergency department, one reported to her local primary care physician, and the third sought over-the-counter relief. The following day, one of the affected employees noted facial skin peeling. All symptoms again resolved over 2–4 days without sequelae.

## METHODS

Photokeratitis was defined as a clinical syndrome lasting up to 48 hours, including a sensation of a foreign body or 'sand' in the eyes and varying degrees of photophobia, lacrimation, and blepharospasm. Conjunctivitis may also occur, often accompanied by erythema of the facial skin surrounding the eyelids.<sup>7</sup> In the cases described, diagnoses of photokeratitis were independently confirmed. A thorough workplace inspection was conducted and it was noted that there was a functional ultraviolet germicidal irradiation (UVGI) lamp in the office. The UVGI lamp had been installed while the office was in use as a sputum induction room, 4 years earlier.

To measure the occupational exposure to UVGI, a calibrated model IL1400 International Light (IL) radiometer connected to a SEL 240 detector (with NS254 and W filters) was used. Permissible exposure times were calculated using the recommended 8-hour exposure limit for unprotected skin and eyes of 6000  $\mu\text{J}/\text{cm}^2$  for UV exposures at 254 nm (the predominant wavelength for UVGI lamps) and dividing the value by the measured irradiance in  $\mu\text{W}/\text{cm}^2$ .<sup>7</sup> This fraction was then multiplied by 8 hours (480 minutes or 28 800 seconds) to convert to the duration of permissible exposure. The Table contains several time and irradiation combinations that result in reaching the occupational exposure limit of 6000  $\mu\text{J}/\text{cm}^2$  (6000

$\mu\text{W}\cong\text{sec}/\text{cm}^2$ ) over a daily 8-hour period on unprotected skin or eyes.

## RESULTS

The fixture and lamp were manufactured by Philips (Croydon, Surrey, UK). The lamp contained one 36-watt bulb, with minimal dust build-up. The lamp was secured to the ceiling (at 3 m) and provided direct irradiation of the area below; no louvers or reflectors were in place. There were no warning signs placed outside the room, and no warning light outside the entrance to indicate when the lamp was in use. The on/off switch to the light was immediately adjacent to the fluorescent bulb on/off switch, and did not have a locking mechanism. There were no reflecting surfaces in the office. Twenty-five centimeters from the UVGI lamp, UV irradiation levels ranged from 179 to 182  $\mu\text{W}/\text{cm}^2$ . The resulting permissible exposure time was therefore from 34 to 33 seconds. At eye level (about 1.7 m) underneath the lamp, UV irradiation ranged from 57.3 to 89.9  $\mu\text{W}/\text{cm}^2$ , which corresponds to a permissible exposure time of 105 to 67 seconds. At seated level at one workstation, UV irradiation ranged 20.0 to 22.2  $\mu\text{W}/\text{cm}^2$  (6 to 5 minutes). At the other workstation, UV irradiation ranged from 34.3 to 49.9  $\mu\text{W}/\text{cm}^2$  (3 to 2 minutes).

## DISCUSSION

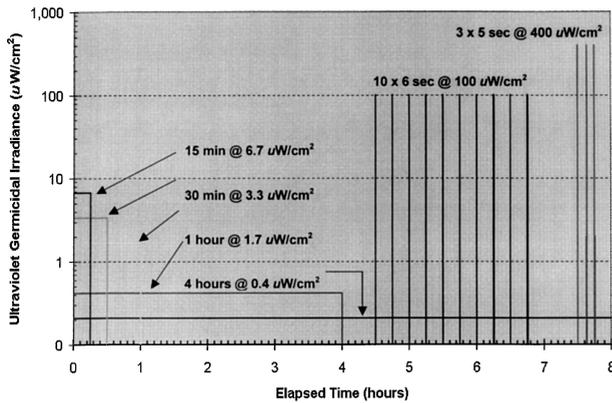
A 'hierarchy of controls' is recommended to reduce the nosocomial transmission of TB.<sup>4</sup> This includes: 1) administrative controls; 2) environmental controls; and 3) personal protective equipment.

Administrative controls are predominantly strategies for the prompt identification and isolation of infectious TB patients. Environmental controls include, among other things, methods to reduce infectious aerosols such as directional ventilation and UVGI lamps with baffles or shielding to limit exposure in the lower portion of a room and to maximize the UVGI in the unoccupied portion of the room. Of note, direct UVGI should not be used for disinfection of surfaces, but rather to kill airborne droplet nuclei. Access to areas with high levels of UVGI and the amount of time one is exposed to UVGI must be limited. Personal protective equipment is the last level of the hierarchy, recommended only when administrative and environmental controls cannot eliminate the risk to the health care worker; it includes protective clothing and shielding.

High levels of UV irradiation were measured in the workplace of the health-care workers described. Occupancy of rooms with unshielded UVGI lamps could be hazardous if personal protective equipment is not worn to protect the skin and eyes, and is to be avoided. The Figure shows several different scenarios in which one would remain below the occupational

**Table** Calculation of exposure time based on irradiance measurements, to limit exposure below the occupational exposure limit of 6000  $\mu\text{W}/\text{cm}^2$

Exposure time	Irradiance (254 nm) $\mu\text{W}\cong\text{sec}/\text{cm}^2$	Occupational exposure limit (254 nm, 8-hr TWA) $\mu\text{J}/\text{cm}^2$
8 hours	0.21	6000
4 hours	0.42	6000
1 hour	1.7	6000
30 minutes	3.3	6000
15 minutes	6.7	6000
1 minute	100	6000
15 seconds	400	6000



**Figure** Different exposure scenarios resulting in UVGI dose equal to the occupational exposure limit (254 nm) of  $6000 \mu\text{J}/\text{cm}^2$ .

exposure limit of  $6000 \mu\text{J}/\text{cm}^2$  ( $6000 \mu\text{W} \cong \text{sec}/\text{cm}^2$ ) over a daily 8-hour period on unprotected skin or eyes. This demonstrates that in some situations one might enter or transit through a room with high irradiance levels without adverse effect to unprotected skin or eyes.

Brubacher et al. reported dermatosis or photokeratitis in five health-care workers exposed to UVGI in an emergency department.<sup>5</sup> Investigation revealed that one of the UVGI lamps was unshielded during the time in which the cases occurred. UVGI irradiation levels as high as  $60 \mu\text{W}/\text{cm}^2$  were measured (location and method of measurement were not described). The resulting allowable exposure time for unprotected eyes and skin was 100 seconds.

Seitz and Decker described transient erythema in a morgue after exposure to six ceiling-mounted, unshielded 30-W UVGI lamps.<sup>8</sup> Warning signs were placed outside the irradiated areas and a warning light was installed outside the morgue entrance to indicate when the UVGI lamps were in use. Personal protective equipment worn included scrub pants, Tyvek/polypropylene gowns, latex surgical gloves, polycarbonate splash shields, a surgical hood (for neck protection), and either dedicated work shoes or shoes with Tyvek covers. UVGI irradiation levels 1.7 m from the floor ranged from 4.7 to  $40.1 \mu\text{W}/\text{cm}^2$ . The resulting allowable exposure times for unprotected eyes and skin ranged from 21 to 2.5 minutes, respectively. Interestingly, Seitz and Decker measured the reduction in UVGI for gloves, surgical hoods and hair

net. UV irradiation was reduced by factors of 2400 to 5800 for gloves, 5–8 for hoods, and, as expected, less than 1 for a hair net.

In our study and in those described above, occupational exposure times for workers with unprotected skin and eyes were seconds to a few minutes, indicating that even brief exposures may result in serious skin or eye burns. Although none of our affected employees could confirm that the UVGI lamp had been switched on during the days symptoms developed, the syndrome is consistent with photokeratitis and skin erythema, caused by the high UVGI levels. In addition, there was no alternative explanation for the syndrome, and, once the UVGI lamp was disabled, there was no recurrence of the clinical syndrome.

Although the office had been converted from its initial use as a sputum induction room, the UVGI lamp had not been removed or maintained with appropriate safety mechanisms. Overexposure might have been prevented by disabling the UVGI lamp when the sputum induction room was converted to office space, by posting a warning notice on the office door, installing an interlock device to switch the UVGI lamp off when anyone entered the room or when the fluorescent bulb was turned on, or by requiring worker protection such as eye protection, UV protection creams and protective clothing.

#### References

- 1 Wells W F, Wells M W, Wilder T S. The environmental control of epidemic contagion. I. An epidemiologic study of radiant disinfection of air in day schools. *Am J Hyg* 1942; 34: 97–121.
- 2 Riley R L, Nardell E A. Clearing the air: the theory and application of ultraviolet air disinfection. *Am Rev Respir Dis* 1989; 139: 1286–1294.
- 3 World Health Organization. Guidelines for the prevention of tuberculosis in health care facilities in resource-limited settings. WHO/CDS/TB/99.269. Geneva: WHO, 1999.
- 4 Centers for Disease Control and Prevention. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities. *MMWR* 1994; 43(RR13): 1–132.
- 5 Brubacher J, Hoffman R S. Hazards of ultraviolet lighting used for tuberculosis control. *Chest* 1996; 109: 582–583.
- 6 Murray W E. Ultraviolet radiation exposures in a mycobacteriology laboratory. *Health Phys* 1990; 58: 507–510.
- 7 NIOSH. Criteria for a recommended standard in occupational exposure to ultraviolet radiation. Cincinnati, Ohio: USDHEW, PHS, NIOSH. DHEW (NIOSH) Publication No. 73-11009. 1972.
- 8 Seitz T A, Decker J A. Health Hazard Evaluation Report: HETA 92-0171-2255. Syracuse, NY: Onondaga County Medical Examiner's Office, September 1992.

#### RÉSUMÉ

Les rayons ultraviolets germicides (UVGI) sont recommandés pour réduire le risque de transmission de la tuberculose (TB) dans les institutions de soins. Toutefois, une exposition excessive peut entraîner de la dermatose et une photokératite. Dans un cadre hospitalier du Botswana, deux infirmières et une nettoyeuse se sont

plaintes d'inconfort oculaire du type 'sable dans les yeux' après avoir travaillé dans un bureau administratif. Le lendemain, une employée a noté une desquamation de la peau du visage. Tous les symptômes se sont résorbés après 2 à 4 jours et sans séquelle. Six semaines plus tard, le syndrome a récidivé chez les trois employées. Une

enquête sur les lieux de travail a révélé que le bureau avait remplacé une salle hospitalière d'induction d'expectorations et qu'une lampe UVGI de 36 watts et sans protection y était toujours installée et opérationnelle. L'interrupteur de la lampe UVGI était au contact direct de l'interrupteur du globe fluorescent et ne comportait pas de mécanisme de blocage. L'Institut National de la Sécurité et de la Santé Professionnelles aux Etats Unis recommande que l'exposition aux UVGI (254 nm) soit inférieure à  $6000 \mu\text{J}/\text{cm}^2$  ( $6000 \mu\text{W}\cong\text{sec}/\text{m}^2$ ) pendant une période

quotidienne de 8 heures sur la peau ou les yeux sans protection. Dans ce bureau, les mesures du UVGI au niveau de l'œil en cas de regard dirigé vers la lampe UVGI s'étendait d'une valeur minimale de  $20.0 \mu\text{W}\cong\text{sec}/\text{m}^2$  en position assise jusqu'à un maximum de  $49.9 \mu\text{W}\cong\text{sec}/\text{m}^2$  en position debout. Ces niveaux d'irradiation ne permettent des temps d'exposition que respectivement de 300 et de 120 secondes et sont le plus probablement la cause des symptômes cliniques décrits.

#### RESUMEN

Se recomienda la irradiación ultravioleta germicida (UVGI) para reducir el riesgo de transmisión de la tuberculosis en los establecimientos de atención de salud. Sin embargo, una exposición excesiva puede producir dermatosis y fotoqueratitis. En un contexto hospitalario en Botswana, dos enfermeras y una ama de llaves se quejaron de molestias oculares como 'arena en los ojos', después de haber trabajado en una oficina administrativa. Al día siguiente una empleada observó una descamación de la piel facial. Todos los síntomas se resolvieron en 2 a 4 días, sin secuelas. Una encuesta en los lugares de trabajo reveló que la oficina había sido instalada en una pieza utilizada anteriormente para la inducción de expectoración y que una lámpara de UVGI de 36 watts, sin protección, estaba todavía funcionando en el

lugar. El interruptor de la lámpara UVGI estaba inmediatamente adyacente al de un tubo fluorescente y no tenía un mecanismo de bloqueo. El Instituto Nacional de Seguridad y de Salud Profesional de EEUU recomienda que la exposición a UVGI (254 nm) sea inferior a  $6.000 \mu\text{J}/\text{cm}^2$  ( $6.000 \mu\text{W}\cong\text{sec}/\text{cm}^2$ ) durante un período cotidiano de 8 horas sobre la piel o los ojos sin protección. En la oficina, las mediciones de UVGI a nivel de los ojos y mirando directamente a la lámpara UVGI iban de un valor mínimo de  $20,0 \mu\text{W}\cong\text{sec}/\text{cm}^2$ , en posición sentada a un valor máximo de  $49,9 \mu\text{W}\cong\text{sec}/\text{cm}^2$ , en posición de pie. Estos niveles de irradiación permiten tiempos de exposición de 300 y 120 segundos, respectivamente, y son probablemente la causa del síndrome clínico descrito.