FEATURE

An assessment of occupational exposures to ultraviolet radiation from transilluminator light boxes in the course of biomedical research procedures

Transilluminators, used in biomedical research, can be a significant source of occupational exposure to ultraviolet radiation (UVR). Ultraviolet exposure can result in biological effects ranging from photokeratitis to erythema. In this study, a comprehensive risk assessment evaluation of transilluminators was performed. The survey data revealed 80% of transilluminators units had some type of engineering control designed into the unit and over 75% compliance with the use of PPE. Self reported adverse health effect such as eye and skin injuries were reported and found significant variable correlated to the presence of a shielded cover on the transilluminators and the availability of a full face shield. While percent compliance is high, recommendation can be made to reduce the possibility of overexposure by instituting a UVR specific training awareness program, purchasing and installing shield covers and implementing a purchasing program to require the purchase of UV transilluminator units to have engineering controls specifically the shield covers.

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INTRODUCTION

Human exposure to ultraviolet radiation (UVR) can occur naturally through sun illumination during outdoor activity or through exposure to artificial sources either voluntarily or occupationally. The potential detrimental effects of exposure to ultraviolet radiation to the human skin and eyes have been well documented.[1–4] Recent growth in the area of biomedical research involving the application of UVR is another area of possible occupational exposure. Occupational exposure to UVR during the analysis of electrophoresis gels using UVR emitting transilluminators, commonly referred to as "light boxes" have not been well characterized. In this study UV transilluminators were evaluated by means of a comprehensive risk assessment survey to determine the level of UVR exposure.

BACKGROUND AND SIGNIFICANCE

Ultraviolet radiation is a form of non-ionizing radiation with wavelengths ranging from 100 to 400 nanometers (nm). Ultraviolet radiation can be categorized into spectral bands: The UV-A region exhibits wavelengths between 315 and 400 nm, UV-B in the region of 280–315 nm and UV-C wavelengths between 100 and 280 nm. The wavelength range below 315 nm is referred to as the actinic range where most chemical and biological reactions occur.

Potential adverse health effects are associated with exposure to ultraviolet radiation include effects on the eyes, skin and immune system. The response of the eye to UVR can manifests as photokeratitis, photoconjunctivitis, retinal burns, cancer and cataracts. Photokeratitis and photoconjunctivitis can result from effects of acute, high intensity exposure and generate a

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feeling of sand in the eye, lacrimination, and severe pain sometimes referred to as "welder's flash" or "arc eye" which are commonly temporary without permanent damage.[5] The most common skin adverse reaction to UVR exposure manifests as erythema or sunburn although chronic exposure to solar radiation increases skin aging. Erythema distress can range from a reddening to blistering of the skin.[1] The absorption of ultraviolet radiation, namely UV-B, causes damage to the human body at the cellular level. The immune system is impacted when ultraviolet radiation is absorbed into cellular components namely DNA and creates mutations by way of thiamine dimers. Although most of the ultraviolet exposure humans receive is from solar radiation, the same adverse effects can occur if exposed to UV in the workplace.

Though no Occupational Health and Safety Administration (OSHA) regulatory standard exists for exposure to UVR, two other health and safety related entities suggested UVR exposure limits. The American Conference of Governmental Industrial Hygienists (ACGIH) suggests an exposure threshold limit value of 0.1 $\mu W\ cm^{-2}$ for the actinic region for an 8-hour period.[6] The National Institute of Occupational Health and Safety (NIOSH) recommends less than one minute of exposure to100 $\mu W\ cm^{-2}$ at 254 nm.[7] The International Commission on Non-ionizing Radiation Protection[5] has established exposure limits (EL) for unprotected eyes and skin not to exceed 30 $J\ m^{-2}$. The Federal Register contains two citations that requires warning labels for the use of UVR emitting devices under the Department of Health and Human Services U.S. Food and Drug Administration: the mercury vapor discharge lamp under section 21 CFR part 1040.3[8] and sun lamps used in tanning beds 21 CFR part 1040.2.[9] Though no legal standard applies to the UVR exposure produced by UV transilluminators, guidelines are available and can be applied to light box use.

UV transilluminators, or light boxes, are commonly used lab equipment that emit wavelengths in the actinic range. A UV transilluminator unit such as a box that encloses a UV light source with filter surface on top of the box (Figure 1). This equipment is used in biomedical research to visualize genetic material. Studies conducted by Klein[10] and Akbar-Khanzadeh and Jahangir-Blourchain[11] measured UVR output from transilluminators utilized in biomedical research and both concluded that exposure measurements taken at their study sites exceeded the 8-hour ACGIH TLV. Additionally Cazzuli and Giroletti[12] measured UV exposure from several instruments used in chemical, genetic and microbiology and biology including UV transilluminators, which were classified as a high risk of exposure to eyes and hands.

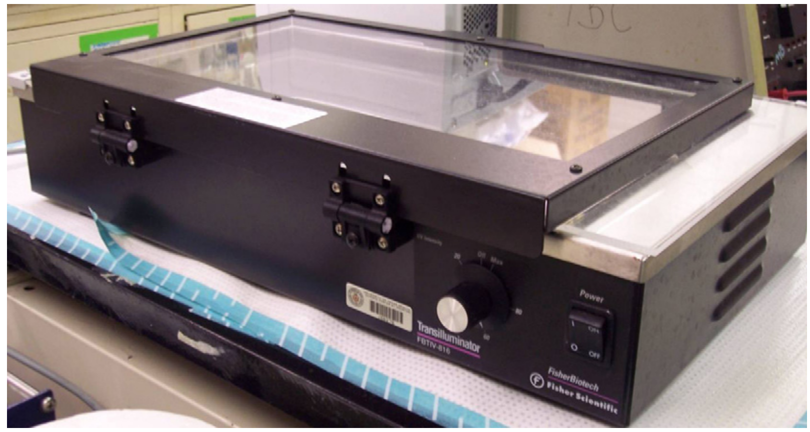

Figure 1. UV transilluminator with a shield and filter protector.

UV transilluminator's safety features evolved from stickered warnings to protective shields to interlocks. The shielding device is made of a thick transparent plastic, some having an additional UV specific coating. Manufacturers of UV transilluminators place warnings on most units indicating that exposure to ultraviolet radiation will result if the unit is not used in accordance with the manufacturers' instructions. The same warning is also included in the unit's instruction manual. Some shielding devices are hinged to allow for easier access and manipulation of the gel which if used in this manner can lead to UVR exposure while other unit incorporate interlocks that require the shield to be in down position before the UV light will work. As an enclosure option, a black curtain can be used to surround and enclose the transilluminator creating a dark room (Figure 2). Other imaging systems completely enclose the transilluminator and combine the photography equipment/software into one unit known as bioimaging systems (Figure 3). Thus the exposure to UVR is virtually eliminated because the UV light source is enclosed and interlocked therefore the ultraviolet light will not when the unit is open. As technology develops, additional safety devices or features will be introduced to eliminate the UVR hazard.

Figure 2. UV transilluminator with a photocurtain.

Figure 3. Bioimaging system. UV transilluminators is located inside pullout drawer.

Once any hazards are identified, engineering and administrative controls along with personal protective equipment (PPE) can be implemented to reduce hazards to the workers. Each of these controls and equipment has advantages and limitations when applied to reducing UVR. Engineering controls are first applied to eliminate the hazard in the equipment design by providing a shield cover or interlocks or by isolating the area where the equipment will be used.

Administrative controls are a second option utilized to reduce the possibility of hazard exposure. Substituting alternative chemical solutions that allow DNA to fluoresce when exposed to visible light thus eliminating the use hazardous chemicals and UV light, however they are not preferred by researchers due to weak bonding with nucleic acids, producing a lack of visual intensity. Implementing a purchasing policy that requires the purchase of units meet specific safety standards and scheduling the use of UVR in time periods where limited numbers of workers are present are examples of administrative control. Training involving the use of UV transilluminators should incorporate UVR hazard identification, adverse health effect recognition and familiarizing the worker with the manufacturer's instruction. Administrative controls rely on personnel to enforce substitution decisions, purchasing practices and oversight to maintain scheduling and training to reduce the hazard.

Personal protective equipment is the last option to protect the user from the hazard because it is a physical barrier worn by the user to separating the user from the hazard. PPE can be cumbersome, bulky and a burden on the user. For those reasons it is the last option employed. PPE to shield the face, eyes and neck can be found by using UV rated full face shield or UV rated safety glasses. To guard the exposed upper extremities, PPE includes gloves to cover exposed hands and long sleeves to cover exposed arms and wrists. A study by Gazik et al.[13] found that latex and nitrile material gloves reduced UVR hand exposure but vinyl did not. Overall, a need for personal protective equipment is essential to eliminate or greatly reduce the amount of exposure from UV light boxes.

In the studies by Klein[10] and Akbar-Khanzadeh and Jahangir-Blourchian[11] both collected measurements of UVR output from UV transilluminators without any shielding in place which demonstrating a possible UV overexposure could occur from using a UV transilluminator if the shield covering is removed from the unit which violates the manufacturers' user instructions and exposes the user to the hazard. Disabling a unit by removing the shielding is not representative of actual laboratory usage; therefore performing an actual UVR risk assessment is needed. Upon reviewing available literature, a set of recognized prudent safety practices were assembled to create a single comprehensive risk assessment survey tool to evaluate the type of unit used, engineering controls, and safety procedures implemented. The purpose of this study is to determine the risk of UVR exposure to workers using transilluminators in normal laboratory settings through the use a comprehensive risk assessment survey tool.

MATERIALS AND METHODS

The study site was a medical complex and the study population included biomedical research workers and laboratories identified as using and housing UV transilluminators. As part of the Environmental Health and Safety Department's routine surveillance program, a database of UV light sources was maintained. By accessing the database, UV transilluminator unit locations were recorded and used as the sample pool. One member from each laboratory was observed using the transilluminator. Laboratory personnel were defined as including a laboratory manager, a technician, assistant or a graduate student. Laboratory personnel were chosen to participate based on availability and prior familiarity using the transilluminators. During the study, laboratory personnel were observed using the transilluminator and answered the study questionnaire. Answers to the questions were noted by marking "yes" or "no" on the survey form and by self reporting to the questions that required explanation. Personnel in labs using UV-transilluminators were asked to self report via the questionnaire the normal practices while using the unit.

RESULTS

Biomedical research laboratories in the study site were inspected for housing and use of UV transilluminators. Two types of UV transilluminators ($n = 62$) used in biomedical research were found during the inspections: 37 tabletop transilluminators and 25 bioimaging systems. Of the 37 tabletop transilluminators units, 27 of the units had shielding while 10 did not have shielding as depicted in Table 1.

Engineering and administrative controls are shown in Table 1 shows as the frequency of light boxes that have applied various engineering controls and the practice of substituting the fluorescent hazardous chemical, ethidium bromide for a less hazardous chemical.

Personal protective equipment available for use was reviewed at the time of inspection. The type of PPE and percent compliance of use of the PPE was assessed and results are summarized in Figure 4.

Self reported adverse health effects, shown in Table 2 indicates that 47

Table 1. Transilluminator Engineering and Administrative Control Frequency

Engineering Controls	Number of Units ($n = 62$)
Bio imaging systems (enclosed)	25
Counter top units	37
Shielded	27
Non-shielded	10
Total number of units	62
Interlocks	13
Timers	5
Warning labels	
Manufacturer applied on unit	38
Safety applied on unit	10
Safety applied on access entry point	30
Isolation	33
Photo curtain	18
Administrative controls	
Substitution	1

Table 2. Self Reported Adverse Health Effects from UV Transilluminator Use

Body Part Affected	Number of Self Reported Injuries ($n = 57$)
Eye	4
Skin	6
Both eye and skin	3
None	47

users experienced no injury, 4 users experienced ocular injury, 6 users experienced skin injury while 3 users reported both eye and skin injury.

The stepwise logistic regression model analysis excluded all independent variables for the model except Shielding 1 (p-value = 0.01) and PPE2 (p-value = 0.07). The presence of a shield on the instrument and the availability of face shield accounted for a large amount of variability in self reported adverse health effects and no other variables (separate area, or gloves) met the 0.10 significant level for inclusion in the model. Analyses were done using SAS Statistical Analysis Software Version 8.2.

Noted during the survey process were additional hazards not accounted for during the initial risk assessment. Unprotected sharps (razor blades) were observed in close proximity to the UV light boxes in 16 of the 62 units surveyed. Razor blades are used to physically cut out the DNA band of interest for further investigation. Also noted, 5 of the 37 countertop transilluminators were placed on cabinet tops immediately inside the laboratory entry and removable filter protectors were observed being used as a shield by 4 laboratory personnel.

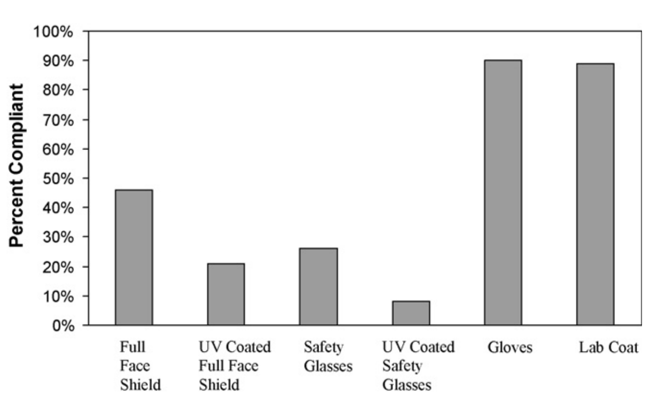

Figure 4. Percentage of user compliance regarding personal protective equipment.

DISCUSSION

Self reported adverse health effects such as an eye injury (photokeratitis or photoconjunctivitis) or skin injury (erytherma) were reported. Of the surveyed users, three self reported both eye and skin injury, four self reported eye injury and six reported skin injury. Survey respondents were not asked to detail what type of transilluminator the injury occurred from, how the unit was being used or when the injury occurred.

The results of this study indicated that shielding on UV transilluminator unit is a significant variable in reducing exposure to UVR. In logistic regression analyses, self reported adverse effects were compared across levels of four independent variables, and shielding presence on the unit and the availability of a full face shield were the variables shown to be a significant factor. Having a separate area available for usage and having gloves available for use did not affect the occurrence of self reported adverse health effects.

While the strong relationship between self reported adverse health effects and shielded units is very plausible, it could also be due to several factors that could not be controlled given the data used in this analysis. This apparent presence of the shield could be a confounder since fewer adverse health effects are expected when using a shield. Such an effect could be accounted for if constant observations were applied rather than relying on self reporting. The Hawthorne effect defined as the tendency for employees to so the job in a nonroutine manner while being observed, could very well have influenced the reluctance of the lab personnel to self report. The survey does not specify a time period of when the events could have occurred and the survey did not indicate to the lab personnel to reveal which type of transilluminator they received an injury from or if the unit was being used improperly. Lastly, the small number of respondents limited the analyses that could be done with adequate power. With a larger dataset, more variables could be more accurately tested for inclusion into a regression model.

Technological advancement in the design of UV transilluminators has resulted in incorporating engineering controls into the units. Engineering controls such as UV enclosure, shielding, timers, interlocks and warning labels are observed in the majority of the transilluminators in the survey population. Enclosed and shielded units account for 84% of the light box population leaving only 16% units without some type of an engineering control.

Administrative controls were practiced in one laboratory. The lab personnel have substituted the fluorescence chemical, ethidium bromide, to an alternative chemical (EvaGreen) that does not require the use of UVR.

A large percentage of compliance was seen in the use of PPE associated with transilluminators. Laboratory coats and gloves were observed in use in 90% and 89% of the survey population, respectively. Face and eye protection was observed by using full face shield or safety glasses of which 26% and 46% respectively, of users comply.

Behavior observed while performing the survey revealed a possibility for exposure not previously discussed. Some manufacturers have an accessory called a filter protector which is a thin UV transmittable plastic covering that is designed to be placed over the top of the UV transilluminator filter surface to protect the filter surface from cuts and scratches. Four surveyed lab personnel members were observed placing the gels on the nonshielded transilluminator surfaces, positioning the filter protector as a body shield and then turning on the UV light switch. When questioned about the practice of using the filter protector as a body shield, the respondents stated that they thought the filter protector was a shield to protect them. The individuals were shown the warning labels, informed of how to properly use the filter protector and educated about the use of PPE.

No record of UVR specific training was accounted for although two labs did have posted warnings of the hazards associated with UVR.

CONCLUSION

The risk assessment survey proved to be a useful tool to provided adequate questions for performing a comprehensive risk assessment evaluation of UVR exposure from transilluminators.

Technological advances have integrated engineering controls into the design of UV transilluminators thus reducing and sometime eliminating the hazardous UVR exposure. Of the surveyed population, 84% of the transilluminators have engineering controls in the form of enclosed UVR or attached shielding to reduce the exposure hazard.

PPE compliance was above 75% for using equipment to protect exposed hands, eyes and face. Use of some form of eye protection (full face shield or safety glasses) was greater than 90%. The use of gloves was 90% and the use of laboratory coat was 89% compliant.

To further reduce the possible UVR exposure, recommendations can be made to develop and implement UVR specific awareness training, appropriate funds for the purchase and installation of shielding covers for transilluminators currently without shielding and to implement a purchasing plan that requires engineering controls such as shielding, interlocks or complete enclosure before the purchase of new UV transilluminators.

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Inventory and Assessment of UV Transilluminators at the University of Texas Health Science Center-Houston

Bldg:________ Room#:________ PI:____________________ Dept:_________________

Manufacturer:_____________________ Model#:____________________ Serial #:______________

What type of unit? Handheld Bioimaging system Counter top

Shielding	Yes	No	N/A
Is shielding present on the instrument?			
Is the shielding unit attached to the instrument?			
Does the shielding unit contain a mechanism control device (interlock) to disable the unit when the shield is not in the down position?			
Is the shielding cracked or scratched?			
Is a separate area available for usage?			
Photo curtain (black curtain around unit)?			
PPE Assessment			
Is the safety face shield mask adjustable?			
Is a safety face shield mask available?			
Does the safety face shield mask have a UV rating?			
Are safety glasses available?			
Do the safety glasses have a UV rating?			
Are gloves available for use?			
What type? Latex Nitrile Rubber Butyl Other			
Is a lab coat (long sleeves and fully buttoned) available and in use?			
Is a UV sticker posted on the door and unit?			
Is a safety posting posted by the unit to explain hazards or usage?			
Observation of Use of UV Transilluminator			
Duration of use of transilluminator?			
Estimated weekly hour workload? (i.e. 3 hour a week, 30 min. a week)			
Has this amount increased and by how much?			
Reason for use?			
User concerns or adverse health events:			

UV-A Output Reading in µW/cm²	**0 in**	**3 in**	**6 in**	**12 in**
Without Shielding Cover on unit				
Average				
With Shielding Cover on unit				
Average				
UV-B Output Reading in µW/cm²	**0 in**	**3 in**	**6 in**	**12 in**
Without Shielding Cover on unit				
Average				
With Shielding Cover on unit				
Average				
UV-C Output Reading in µW/cm²	**0 in**	**3 in**	**6 in**	**12 in**
Without Shielding Cover on unit				
Average				
With Shielding Cover on unit				
Average				
User Reading in µW/cm²	**0 in**	**3 in**	**6 in**	**12 in**
Without Shielding Cover on unit				
Average				
With Shielding Cover on unit				
Average				