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Ultraviolet Protectants: Causative Agents for Screen and Image Artifacts in Radiography[1]

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Abbreviation:
UV = ultraviolet

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PURPOSE: To determine the specific causative agent(s) and mechanism of formation of opacity artifacts seen on some radiographs acquired at the authors' facility.

MATERIALS AND METHODS: Various substances likely to come into contact with technologists' hands were tested. Initial test results showed that a hand lotion with sun protection produced artifacts similar to the ones seen clinically and left no visible evidence on the screen after cleaning. Further experimental findings showed that substances without sun protection did not produce the artifacts, while other products with sun protection did produce artifacts. The four most commonly used active ingredients (ultraviolet [UV] filters) in products with sun protection were tested to determine if they produced artifacts. The temporal dependence and penetration depth of the causative agent(s) were determined. A sample of screens commonly used in radiology departments was tested to determine if artifacts were produced.

RESULTS: Each of the UV filters tested caused artifacts when added to a lotion that had no sun protection and did not produce artifacts by itself. The UV filters quickly penetrated the protective layer of the screens and therefore could not be removed with conventional cleaning methods. Artifacts appeared only when using screens with a primary emission in the UV portion of the spectrum.

CONCLUSION: The UV filters in the products with sun protection absorb the UV light emitted by the screens and cause artifacts. Screens with UV emissions are susceptible to artifacts from the use of UV protectants.

A number of radiographs developed in the same darkroom with use of hand-loaded book cassettes began to exhibit similar artifacts at our facility. The artifacts tended to occur in the corners of the image, where technologists who loaded the cassettes were likely to handle the film. In some instances, the artifacts appeared to be images of fingers (Fig 1). Artifacts due to handling were investigated first, but various attempts at poor film handling were unsuccessful in reproducing the artifacts. Rather, it was found that multiple radiographs obtained with the same cassette showed identical artifacts.

To determine the extent of the artifact, all book cassettes in the area were cleaned (intensifying screen cleaner and antistatic solution; Eastman Kodak, Rochester, NY) and tested for screen uniformity by imaging a uniform polymerized methyl methacrylate phantom. Images obtained with nearly half of the cassettes exhibited the artifact to various degrees. Affected cassettes were removed from clinical use. A visual examination with use of white and ultraviolet (UV) lights revealed no obvious defects of the cassettes. The screens were cleaned again with special consideration given to the areas suspected of causing the artifacts. A second uniformity test of the affected screens showed that there was no change in the shape or intensity of the artifacts.

Because of the shape and location of the artifacts, it was suspected that a contaminant from the technologists' hands was being deposited on the screens. It was postulated that the contaminant was being transferred from their hands to the film and eventually to the screens. The purpose of our study was to determine the specific causative agent(s) and mechanism of formation of the artifacts seen on some radiographs acquired at our facility.

MATERIALS AND METHODS

Determination of the Causative Agent(s)

A partial list of substances (Table 1) that the technologists might come into contact with during normal working conditions was compiled. A radiographic screen (Sterling UV Fast Detail; Agfa-Gevaert, Mortsel, Belgium) was partitioned into regions, and a small amount of substances 1–10 was applied to each region. Opaque film was taped over the second screen in the cassette to block light emission. A piece of scrap film was placed over the samples, and the cassette was closed. After 30 minutes, the scrap film was discarded, and the cassette was loaded with unexposed film. A precleaning image was acquired with a background optical density of approximately 1.3. The screen was then cleaned thoroughly with cassette screen cleaner to remove all visible traces of the substances. Special care was taken to avoid cross-contamination of the samples. A postcleaning image was acquired with the same technique.

The pre- and postcleaning images were placed side by side on a view box. By using the precleaning image as a reference, the postcleaning image was examined for artifacts in the region where the substances had been applied.

In the original substances tested (substances 1–10, Table 1), it was observed that an artifact occurred only on the postcleaning image with substance 9, a lotion containing UV protectants. Various additional topical lotions and similar products with and without UV protection were collected (substances 11–15; Table 1). These lotions were tested as described previously. The follow-up test of substances 11–15, with and without UV protection, showed that only samples containing UV filters caused artifacts.

To determine the specific causative agents, four commonly used commercially available active agents (UV filters) were obtained (Table 2). Since substance 10 (Table 1) lacked UV protection yet had a nearly identical list of inert ingredients compared with other lotions that contained UV filters, it was used as a base for our test substances, which were obtained by mixing the base with the UV filters. Water was added to substance 10 until it was thinned enough that volumes could be measured accurately. The thinned lotion was separated into five 25-mL specimens. One of the UV-filtering chemicals in Table 2 was added to each of the specimen containers to make a 4% solution by volume, with one specimen left as a control sample. A 4% solution was chosen because it was at or below the maximum concentration levels specified by the U.S. Food and Drug Administration for each of the UV filters (1) and was typical of the concentrations in commercial products. The four samples and the control sample were also tested with a Sterling UV Fast Detail (Agfa-Gevaert) screen, as described previously.

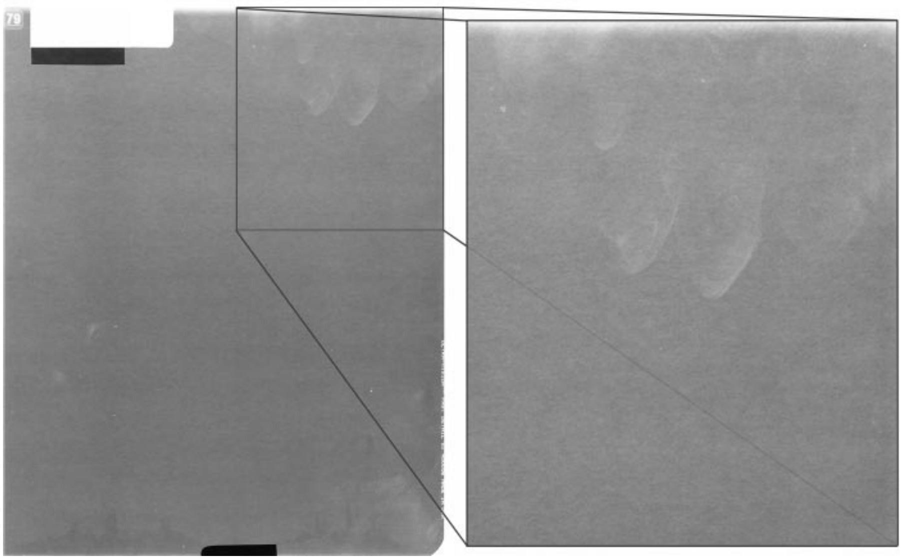

Figure 1. Radiograph obtained with a 10 × 12-inch book cassette that was removed from clinical use because of obvious artifacts (left). The artifacts in the upper right region resemble marks left by four fingers while holding the film. Note the magnified view (right) of the region that contains artifacts in the shape of fingers.

Mechanism and Extent of Screen Damage

Time-dependent damage.—To determine how quickly the damage occurs to the screen, regions were marked off on a Sterling UV Fast Detail (Agfa-Gevaert) screen, and consistent amounts of substance 13 (Table 1) were applied to each region. A piece of opaque film was taped over the second screen in the cassette to block light emission. A piece of scrap film was placed over the samples, and the cassette was closed. After waiting predetermined amounts of time (7–20,500 minutes), one region was cleaned, and the date and time were recorded on the tape beneath it. A new piece of scrap film was placed over the samples, and the cassette was closed. These steps were repeated until all of the regions had been cleaned. After the last of the regions was cleaned, an image was acquired with a background optical density near 1.3. We measured the difference in optical density between the background and the artifacts in each region.

Penetration of the screen by UV filters.—To determine if the UV filters were binding to the surface or penetrating the protective layer of the screen, substance 13, which contained UV filters, was applied to an unused portion of the same screen. A piece of scrap film was placed over the sample. The cassette was closed for 1 day to obtain the maximum difference in optical density between the artifact and the background. At that time, the screen was cleaned with cassette cleaner so that all visible traces of the sample were removed. An image was acquired with an optical density near 1.3. One author noted the difference in optical density between the background and the artifact. The screen was scrubbed with 70% isopropyl alcohol solution and a soft cloth. The screen used for this test included a Tyril (Agfa-Gevaert) protective layer. This material, which was used with many of the manufacturer's older screens, is slightly soluble in isopropyl alcohol. Therefore, scrubbing with this solvent will remove a small amount of the protective layer and any contaminants bound to it (D. Richards, oral communication, 2001). A second image was acquired with the same technique. One author again measured the difference in optical density between the background and the artifact. The optical densities were

TABLE 1
Substances Tested to Determine if They Cause Artifacts When in Contact with Intensifying Screens

Substance No.	Substance	Manufacturer Name and Location	Sun Protective Factor	UV Filters
1	Airkem Handsoap	Ecolab Airkem Professional Products, St Paul, Minn	. . .	. . .
2	Alcohol Prep Pad	Kendall, Mansfield, Mass	. . .	. . .
3	Betadine solution	Purdue Frederick, Stamford, Conn	. . .	. . .
4	Barium sulfate	E-Z-Em Canada, Westbury, NY	. . .	. . .
5	Disinfectant spray	3M, St Paul, Minn	. . .	. . .
6	Hydrogen peroxide	HUMCO, Texarkana, Tex	. . .	. . .
7	Keri Silky Smooth Lotion	Bristol-Myers Squibb, New York, NY	. . .	. . .
8	Bath & Body Works Anti-Bacterial Hand Gel	Bath & Body Works, Reynoldsburg, Ohio	. . .	. . .
9	Pond's Nourishing Moisturizer Lotion	Chesebrough-Pond's USA, Greenwich, Conn	15	2-Ethylhexyl p-methoxycinnamate*
10	Pond's Nourishing Moisturizer Lotion	Chesebrough-Pond's USA, Greenwich, Conn	. . .	. . .
11	Vaseline Intensive Care Renew & Protect	Chesebrough-Pond's USA, Greenwich, Conn	5	2-Ethylhexyl p-methoxycinnamate*
12	Vaseline Intensive Care Aloe & Naturals	Chesebrough-Pond's USA, Greenwich, Conn	. . .	. . .
13	Lubriderm Daily UV Lotion	Pfizer, Morris Plains, NJ	15	7.5% Octyl methoxycinnamate, 4.0% octyl salicylate, 3.0% oxybenzone
14	Neutrogena New Hands	Neutrogena, Los Angeles, Calif	15	7.5% Octyl methoxycinnamate, 4.0% oxybenzone
15	Blistex Daily Conditioning	Blistex, Oak Brook, Ill	20	7.5% Octyl methoxycinnamate, 4.5% oxybenzone

Note.—Substances 1–10 are a sampling of items collected in the clinical setting. Substances 11–15 are a sampling of common topical agents.
* Concentrations not available.

TABLE 2
UV Filters Prevalent as Active Ingredients in Sunscreens for Filtering UV Radiation

Common Name	Chemical Name	Chemical Abstract Service Registry No.	Maximum Concentration (%)*
Oxybenzone	2-Hydroxy 4-methoxybenzophenon	131-57-7	6.0
Octyl methoxycinnamate	Octyl 4-methoxycinnamate	5466-77-3	7.5
Octyl salicylate	2-Ethylhexyl salicylate	118-60-5	5.0
Padimate O	Octyl p-dimethylaminobenzoate	21245-02-3	8.0

Note.—Filters were combined with a lotion that did not produce artifacts to determine if UV filters cause permanent artifacts when in contact with intensifying screens.
* According to the U.S. Food and Drug Administration (1).

compared to determine if there was a change in the intensity of the artifacts.

To further examine the penetration of the UV filter into the protective layer of the screen, 800-grit sandpaper was used to remove incremental amounts of the protective layer over the artifact. The screen was cleaned thoroughly, and an image was acquired. The image was examined by the authors to see if there were any changes in the artifact. This process was repeated until the entire protective laver was removed.

Damage to various screens by UV protectants.—The test screen used in this study is made with UV-emitting $YTaO_4$ phosphor. To determine if the artifact was limited to screens with UV-emitting phosphors, a variety of screen types were tested as described previously by using the substances in Table 2 and a control sample.

RESULTS

Determination of the Causative Agent(s)

All of the UV filters (Table 2) when tested separately left an artifact (Fig 2) on the postcleaning image. Oxybenzone and octyl methoxycinnamate left opacity artifacts that are well defined. Octyl salicylate left a fainter artifact. Padimate O left a faint artifact with poorly defined edges that is difficult to see.

Mechanism of Screen Damage

Time-dependent damage.—The amount of time that the UV filtering agent is left on the screen has an exponential dependence (Fig 3) on the optical density of the artifacts for approximately the first 1,000 minutes. After 1,000 minutes, there does not appear be much additional effect. The slight variation in optical density is due to the varying amounts of lotion applied to the screen.

Penetration of the screen by UV filters.—The differences in optical density between the artifacts and the background from images obtained before and after scrubbing with the isopropyl alcohol were the same (0.82). After sanding, the images showed that the artifact was persistent, although occasionally at a somewhat reduced intensity, until the entire protective layer was removed and the phosphor crumbled away.

Damage to various screens by UV protectants.—Screens with Gd_2O_2S:Tb phosphor (Table 3) have a peak emission (Curix Ortho Regular. Technical data sheet no. M1-00244. Mortsel, Belgium: AGFA-Gevaert.) (Fig 4) well above the absorption range (2) of the UV filters and

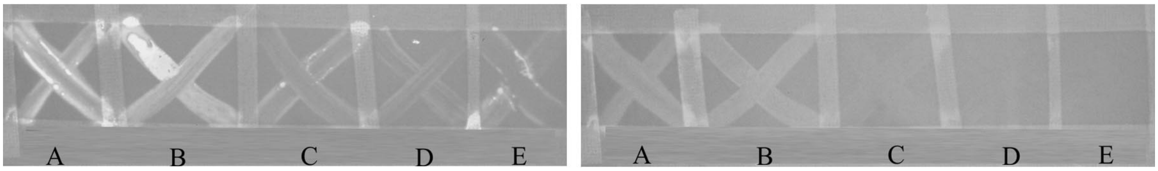

Figure 2. Radiographs of a lotion without UV protectants to which different UV filters were added to make a 4% solution by volume. Left: Image obtained with substances placed on the screen. Right: Image obtained after the screen had been cleaned of all visible traces of the substances. All of the UV filters caused artifacts of varying intensities, and the control sample did not produce an artifact. *A,* oxybenzone; *B,* octyl methoxycinnamate; *C,* octyl salicylate; *D,* padimate O; *E,* control sample.

did not have permanent artifacts. Screens with $YTaO_4$ phosphor (Table 3) have emission spectra (Curix Ultra Rapid and Ultra Vision Fast Detail. Technical data sheet nos. H-35912-3 and H-35912-2, respectively. Mortsel, Belgium: AGFA-Gevaert.) (Fig 5) that overlap the absorption range (2) of the UV filters, and these screens showed artifacts caused by all of the UV filters tested. However, screens with $YTaO_4$:Nb or Ba(Sr)SO_4:Eu phosphor (Table 3) have emission spectra (Quanta Fast Detail. Technical data sheet no. H-55241. Mortsel, Belgium: AGFA-Gevaert; and X-Omatic Regular, 2851-97-71. Rochester, NY: Eastman Kodak.) that slightly overlap the absorption range (3) of the UV filters (Figs 6, 7). The presence of artifacts is somewhat more tenuous as a consequence. We detected an artifact only with the UV filter octyl salicylate on the $YTaO_4$:Nb phosphor and only with oxybenzone on the Ba(Sr)SO_4:Eu phosphor.

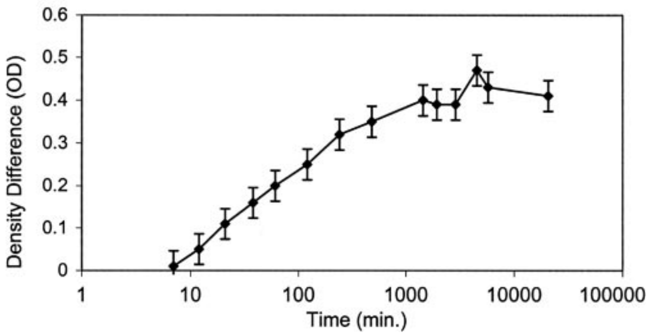

Figure 3. Graph shows differences in optical density *(OD)* over time. Consistent amounts of UV protectants were applied to a $YTaO_4$ intensifying screen and then cleaned off after varying lengths of time. The optical density difference was measured for each of the artifacts produced.

TABLE 3
Commonly Used Radiographic Screens Tested for Permanent Artifacts due to UV Filters

Screen Type	Manufacturer Name and Location	Phosphor	Artifacts
UV Fast Detail	Agfa-Gevaert, Mortsel, Belgium	$YTaO_4$	Yes
Quanta Fast Detail	Agfa-Gevaert, Mortsel, Belgium	$YTaO_4$:Nb	Yes*
Curix Ultra Rapid	Agfa-Gevaert, Mortsel, Belgium	$YTaO_4$	Yes
Ortho Regular	Agfa-Gevaert, Mortsel, Belgium	Gd_2O_2S:Tb	No
Lanex Regular	Eastman Kodak, Rochester NY	Gd_2O_2S:Tb	No
Min-R	Eastman Kodak, Rochester NY	Gd_2O_2S:Tb	No
X-Omatic Regular	Eastman Kodak, Rochester NY	Ba(Sr)SO_4:Eu	Yes†

* Only octyl salicylate caused a visible artifact.
† Only oxybenzone caused a visible artifact.

DISCUSSION

The use of hand lotions that contain UV protectant(s) likely caused the original artifact seen in our clinic. The technologist would have transferred the UV protectant to the film while loading the cassette. The film was then closed in the cassette and left for a period of time, sometimes overnight. The UV protectant came into contact with the screen and quickly started to penetrate the protective layer. From this point on, when the screen was used, the UV light emitted from the $YTaO_4$ phosphor was partially absorbed (filtered) by the UV filter(s) present in the protective layer of the screen, which caused opacity artifacts on each radiograph.

All of the samples of commercial products that contained UV protectant(s) caused artifacts to varying degrees on screens with $YTaO_4$ phosphor. Unfortunately, unless lotions containing UV protectants are immediately cleaned from these screens, the UV filters seem to penetrate beyond the topmost surface of the protective layer of the screen, and the artifact becomes permanent. At this point, the screen will most likely have to be removed from clinical use depending on the size, location, and intensity of the artifact.

The ability of a UV filter to cause artifacts and the intensity of the artifact can be attributed to a number of other factors besides the phosphor used in the screen. These include concentration of the UV filters and ability of the protective layers (top coat) of different screens to prevent penetration of the UV filter.

Contamination from the use of products containing UV protectants is likely to cause artifacts on screens that emit in the UV spectrum. Clinics that use UV-emitting intensifying screens should be aware of this potential cause of artifacts on images obtained with hand-loaded cassettes. To help in the prevention of this type of artifact, the technologist should be reminded of proper film-handling techniques. The use of clean examination gloves when loading and

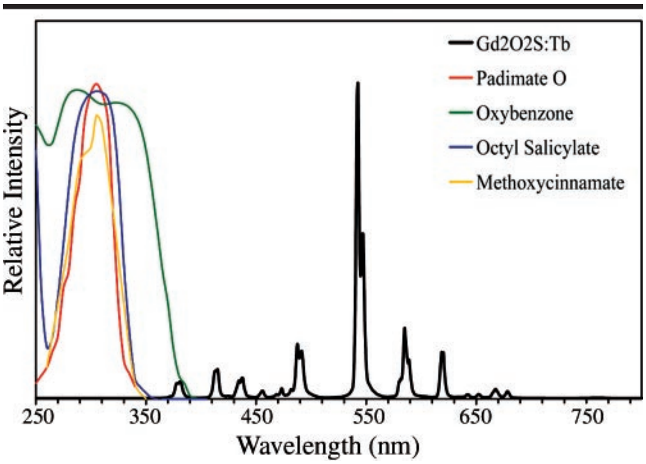

Figure 4. Spectroscopic image shows that the absorbance range of the UV filters does not substantially overlap the emission spectrum of Gd_2O_2S:Tb phosphor.

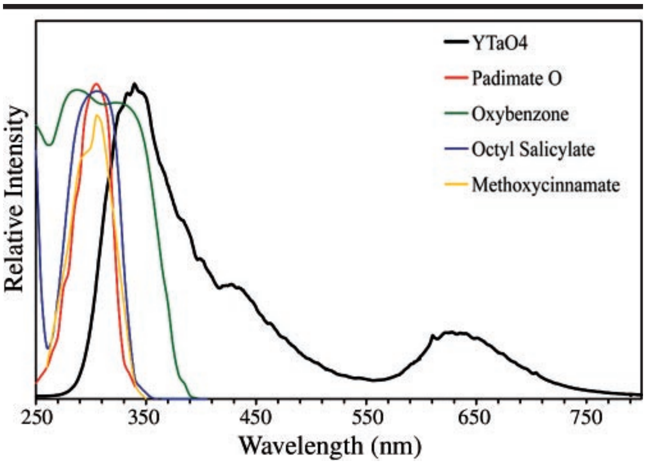

Figure 5. Spectroscopic image shows that the absorbance range of the UV filters overlaps considerably with the emission spectrum of $YTaO_4$ phosphor.

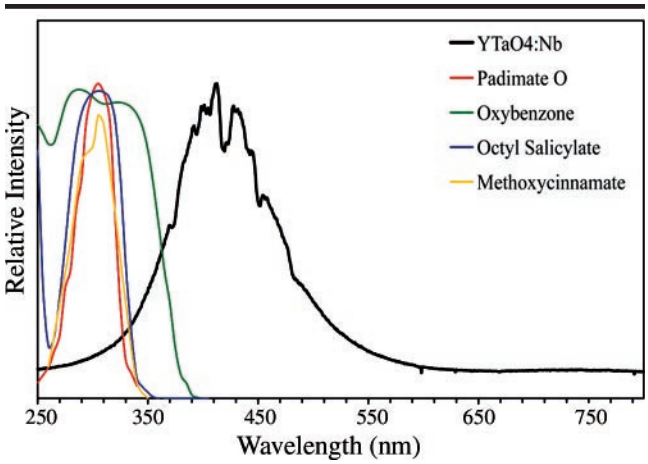

Figure 6. Spectroscopic image shows that the absorbance range of the UV filters overlaps the tail of the $YTaO_4$:Nb phosphor emission spectrum.

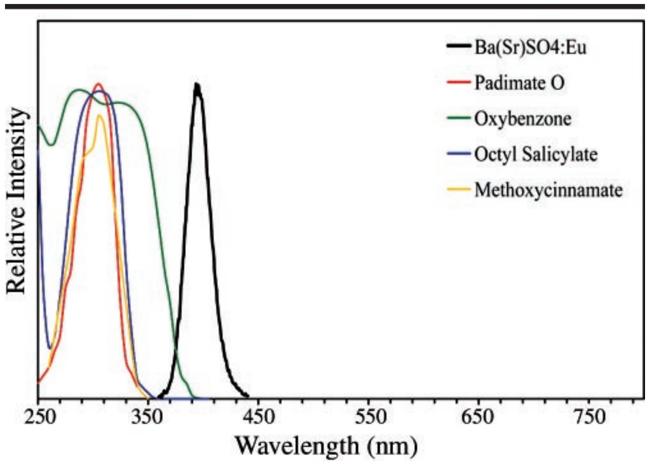

Figure 7. Spectroscopic image shows that the absorbance range of the UV filters overlaps the tail of the Ba(Sr)SO_4:Eu phosphor emission spectrum.

unloading cassettes should reduce the contamination of the screens by cosmetics. Also, regular uniformity testing is an important part of every quality assurance program, especially if UV-emitting phosphors are used.

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