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The Detection and Documentation of Trace Wound Patterns by Use of an Alternative Light Source

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ABSTRACT: This article is a discussion of the use of narrow-band light sources coupled with cameras equipped with band-pass filters to document patterned injuries on human skin. Several case reports are included.

KEYWORDS: forensic science, patterned injuries, light sources

Photographic documentation of wound patterns by the use of reflective ultraviolet radiation is well noted in the literature. The enhancement or discovery of patterned injuries on the bodies of victims has aided the investigation of crimes. This success has lead to research in the illumination of tissues by other wavelengths of the electromagnetic spectrum (see Fig. 1) and the incorporation of fluorescence photography into the arsenal of the investigator. Crime-scene investigators have been researching the fluorescent properties of fingerprints for several years now. Although there is currently a debate about who was first to do so and who was the first to adapt the light sources now used for this type of investigation, we were the first to apply these principles and the high-intensity light sources to observe fluorescence of wounds on human skin. We have elected to term this type of photography of patterned wounds Alternative Light Imaging. The use of alternative light to scan the bodies of victims of violent crimes and suspects in those cases has yielded surprising results. A review of the photobiological properties, photographic parameters, and some case histories will be discussed.

Theory

This technique is possible because of the phenomenon of Stokes shift. When light strikes human skin, some is reflected, some is transmitted to deeper layers, some is scattered and some is absorbed by molecules in the tissues known as chromophores [*1*].

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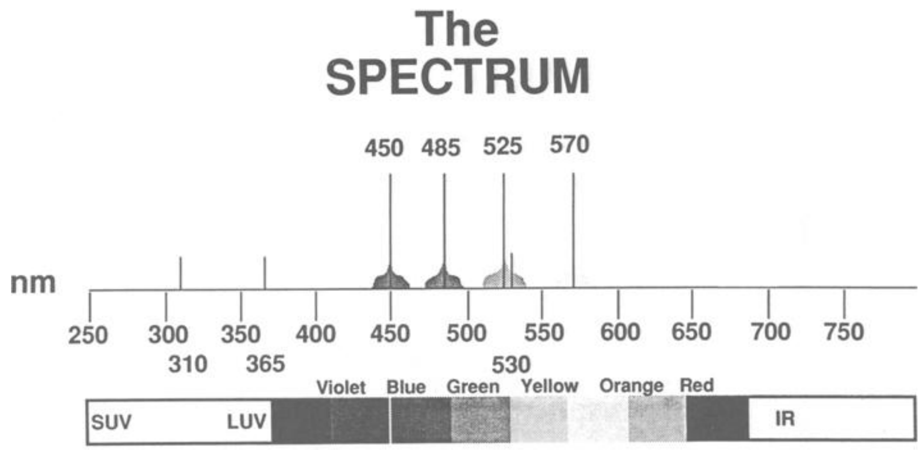

Figure 1. The spectrum:

Ultraviolet	14 nm - 400 nm	Visible Light	400 nm - 700 nm
14 nm - 310 nm	Short UV	Infra Red	greater than 700 nm
310 nm - 400 nm	Long UV	Alternate light generator (Omni Print 1000™)	
310 nm - lower limit of transmission through glass		4 narrow bamds: 450, 485, 525, and 570 nm	
365 nm - peak transmission through 18A filter		2 wide bands: <530 nm and all white light	

FIG. 1—*The spectrum.*

The molecules and atoms of the tissue that absorbs part of the energy of the light become excited, and the electrons within these atoms may move to higher energy orbits. Upon the return of these electrons to their normal, nonexcited states, they release energy which can be a photon (a quantum of light energy). In other words, they will glow or to use the scientific term, they fluoresce. This fluorescent light is always of less intensity and of a longer (less energetic) wavelength (see Fig. 2). In fact, it is often quite faint and only occurs while the original excitation energy (light) is applied. Therefore, it cannot be readily observed by the eye. However, if one views the material through a filter that blocks the return of the excitation light, then only the fluorescence of the tissue can be visualized. In order to accomplish this, the material being examined is viewed through colored goggles that are designed to block the reflected light and pass only the fluorescent light emitted by the tissues (see Fig. 3).

To help understand the technique, one can examine the different light intensities needed for illumination in fingerprint fluorescence. Sunlight at the equator produces about 10 milliwatts/cm^2 in the blue-green spectrum between 400 to 520 nm. In order to produce fluorescence in the fingerprint, light intensities of between 100 milliwatts/cm^2 to 1 watt/cm^2 are required. In other words, a source 10 to 100 times more powerful than sunlight is needed. The human eye, when given sufficient time to adapt, can detect illumination caused by moonlight which is only one-millionth the intensity of sunlight. The fluorescence emitted from the fingerprint is 10^{-7} or ten million to one times less brilliant. Adding in the factor of surface reflectance from the excitation illumination, requires the use of an interference filter that is able to reduce the illumination or excitation light by a factor of 10^{-8} in order to visualize the fluorescence [*2*].

"A theory that accounts for the optical properties of the skin in the visible region of the spectrum has been derived by combining established formulae, relating to light absorption and scattering. The spectrum of normal skin is dominated by the summed absorbances of hemoglobin and melanin, with small contributions from fibrous protein,

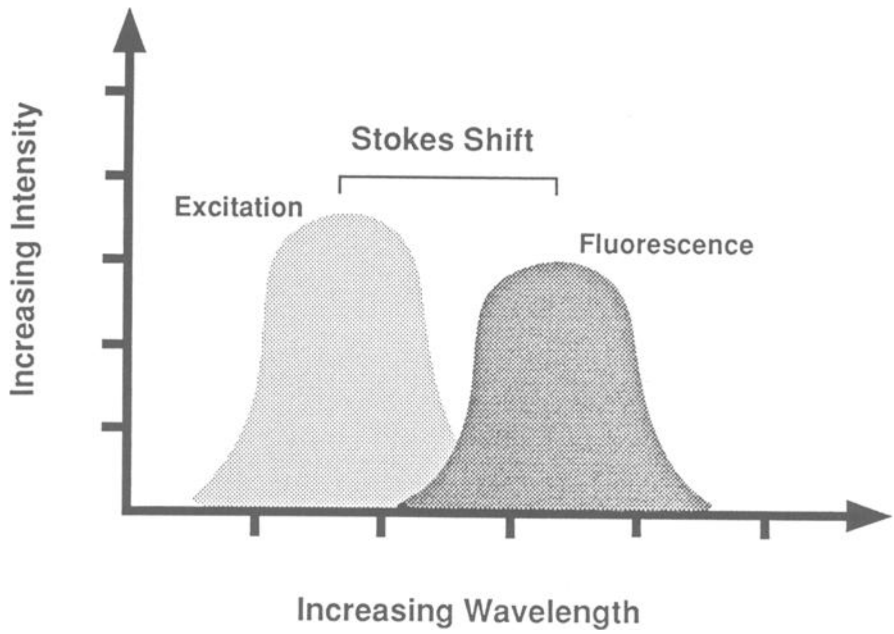

FIG. 2—*Intensity and wavelength of the excitation light (radiation) compared to the fluorescence. Fluorescence is always of lesser intensity and longer wavelength than the excitation light. This is referred to as "stokes shift."*

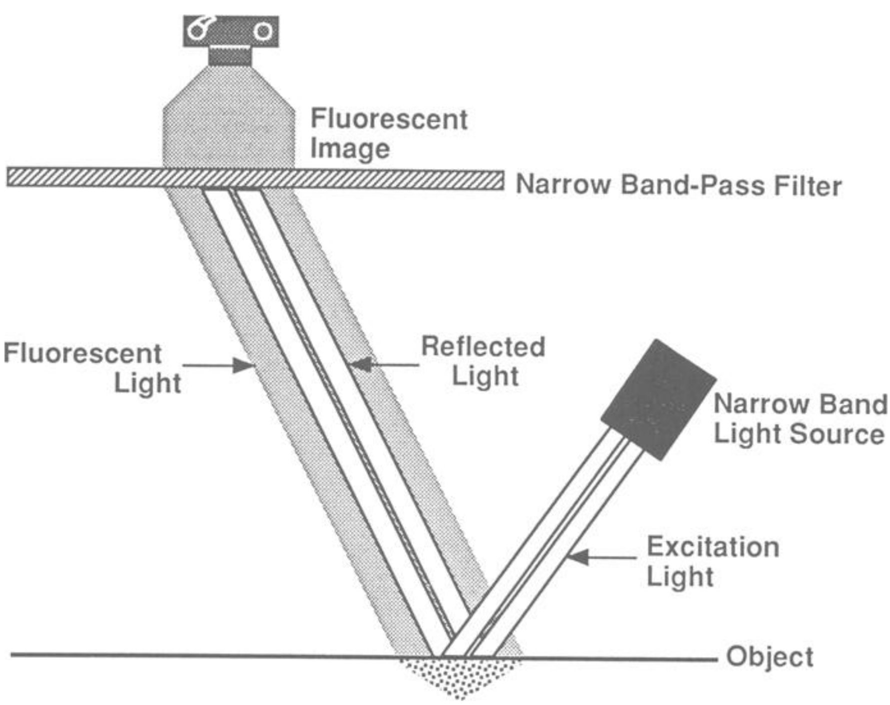

FIG. 3—*As the excitation light strikes a surface, two phenomenon occur: reflectance and fluorescence. Use of the proper band-pass filter restricts the light reaching the film to only the fluorescent image.*

collagen and fat" [3]. Different components in human skin and its biological building blocks have varying absorption and fluorescence curves. Hemoglobin absorbs ultraviolet radiation because it contains protoporphyrin. Carotenoids also absorb ultraviolet radiation [4]. Spectroscopic absorptive differences between healthy and diseased or traumatized tissue have been used to scan for diseases as diverse as cancer and dental decay [5]. This enables one to view patterned injuries, trauma and the healing processes by noting the varying degrees of absorption and fluorescence by the different biological components.

Materials

A high intensity tunable light source is required. The Omniprint® 1000 (Omnichrome, Inc., Chino, CA) is designed to detect and document trace evidence such as hair, fiber, body fluids, shoeprints and of course fingerprints [6]. This device, a tunable wavelength light source, developed for forensic examination of trace evidence delivers illumination through a six foot fiber optic cable or directly through the light aperture without the cable. The user can select one of six wavelength bands via a rotary switch on the front panel. There is a choice of four narrow band and two wide band output wavelengths. The narrow band wavelengths are centered at 450 nm, 485 nm, 525 nm, and 570 nm and each is about 30 nm wide. The two wideband wavelengths are white light and all wavelengths less than 530 nm.

We use a manual 35 mm single lens reflex (SLR) camera with a 50 mm macro lens. Kodak T-Max® 3200 ISO and Ektapress® 1600 ISO color film have been found to be the films of choice and may be push processed at 6400 ISO. The fine grain of these films allows for excellent contrast and detail. Various color filters and filter adapters are required. As in ultraviolet photography, each camera system must be fine tuned for optimal results.

Method

Reflectance, absorption and transmission of light through the lens is the critical factor. Therefore, the proper positioning of the light source is critical to success. This examination must be conducted in total darkness, any extraneous light will wash out the fluorescent return from the tissues. The light pattern emanating from the fiber optic cable is designed to concentrate light into a small area. When illuminating an area of 8 to 12 inches in diameter there can be a great fall-off of light intensity across the circle. A five *f*-stop difference between the center and the edge is possible. To overcome this, the fiber optic cable must be placed at a distance from the subject, approximately 17 inches or further to yield only a one *f*-stop difference from center to edge. Since much of the energy of the light is lost in transmission through the fiber optic cable, the focusing lens can be removed and placed directly on the light aperture greatly increasing the usable light. The light source can be mounted on a tripod in order to facilitate positioning. A new, smaller unit is under development which will include a short, semirigid fiber optic which should also assist the investigator in positioning the light source.

The investigator must illuminate the subject and view the field through colored goggles which are supplied with the unit. Red, orange, or yellow lenses act as a band-pass filters. Although mere illumination with the high intensity light source may improve visualization of the wounds, the true benefit comes from the fluorescence of the tissues when viewed through the goggles. Unlike reflective ultraviolet photography, the photographer can actually see the wound image before making the exposure.

We have had the best success using the 450 nm wavelength and the yellow lenses. Omnichrome supplies colored plexiglass made from the same material as the viewing goggles that can be used as photographic filters. Cut a piece large enough to fit into a filter holder, such as a Cokin® (U.S. Distributor—Minolta Corp., Ramsey, NJ) and mount the holder on the front of the lens.

Exposure factors are difficult to generalize, each camera system and light source must be individually calibrated. In addition, there are several manufacturers of alternative light sources (Omniprint®, Polilight®, and Lumilite®) and each utilizes a slightly different optical set-up to direct the illumination to the target. The authors have also found that intensity decreases markedly with bulb age, in fact in one recent case there was an eight *f*-stop variance between an old bulb and a newly installed bulb. To calibrate the system the authors recommend that the photographer use a visible light meter to determine a light-to-subject distance which yields an illumination pattern with no more than a one *f*-stop variance from center to edge. The exposure latitude of most films will compensate for this small difference. The fiber optic cable can also degrade the illumination by a factor of one-half. Exposures have ranged from one-half second to ISO 6400 from an old bulb to 1/500 of a second at 3200 ISO for a new bulb. Since the image is in the visible spectrum, if the camera has through the lens metering, exposures can be set automatically. Long exposures will require a tripod and one should try to avoid using a fully opened lens. We are currently researching a technique using the electronic flash for illumination in order to simplify the procedure. In any case, one must always bracket the exposures and various skin tones will effect the results. One can never take too many pictures.

Case Reports

Case One

Three people were found murdered by stabbing with multiple incisions on each victim. A large butcher knife was identified as the murder weapon by wear patterns and notches on the blade that corresponded to irregularities in the borders of the wounds. The handle of the knife was wooden and riveted to the shank. On the right side the wood was missing, exposing two intact rivets and one broken rivet. A suspect was examined ten days after the assault and a fluorescent wound pattern exactly matching the rivets could be demonstrated in the palm of his hand using the alternative light source. This patterned injury was not visible under normal light or reflective ultraviolet imaging. See Fig. 4.

Case Two

Three juveniles were charged with the murder of an elderly woman who had been bludgeoned to death with a length of galvanized water pipe. Four days after the assault, the hands of each of the three suspects were examined using the high intensity alternative light source. On the palm of one of the suspects a pattern consistent with the thread pattern of the pipe was demonstrated and photographed. See Fig. 5.

Case Three

A 24-month-old child whose death was thought to be due to Shaken Infant Syndrome was brought to the morgue. The body was examined under alternative light and a pattern consistent with someone holding the child by the chest and under the arms was visualized. After the body had been embalmed, the pattern could no longer be seen on a second scan with the alternative light source.

Case Four

A 28-year-old, white female was kidnapped, raped, and murdered. A ligature made from her purse strap was found around her neck. A broken buckle hung at the end of

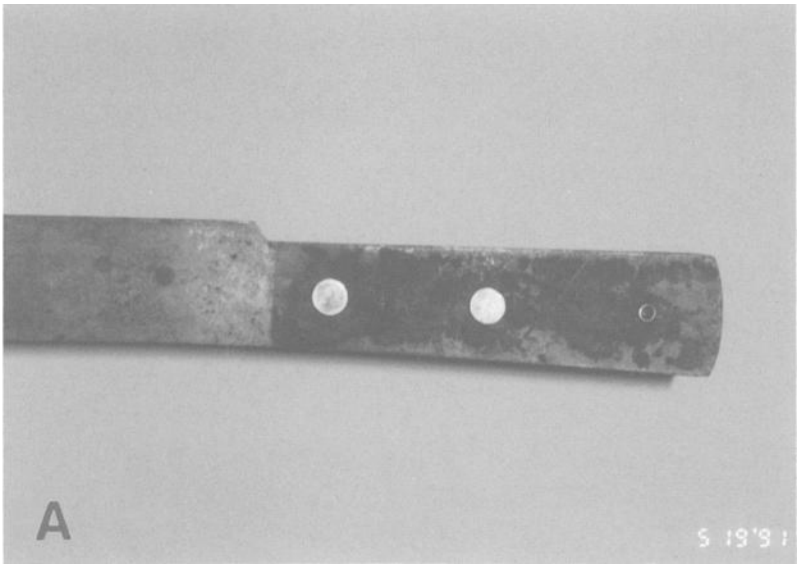

FIG. 4A—*The handle of the knife, please note the two remaining large metallic rivets.*

FIG. 4B—*Alternative light illumination and imaging clearly demonstrates the patterned injuries left by the rivets in the hand of a volunteer who struck an object with the knife. A similar pattern was demonstrated in the hand of the suspect in Case I.*

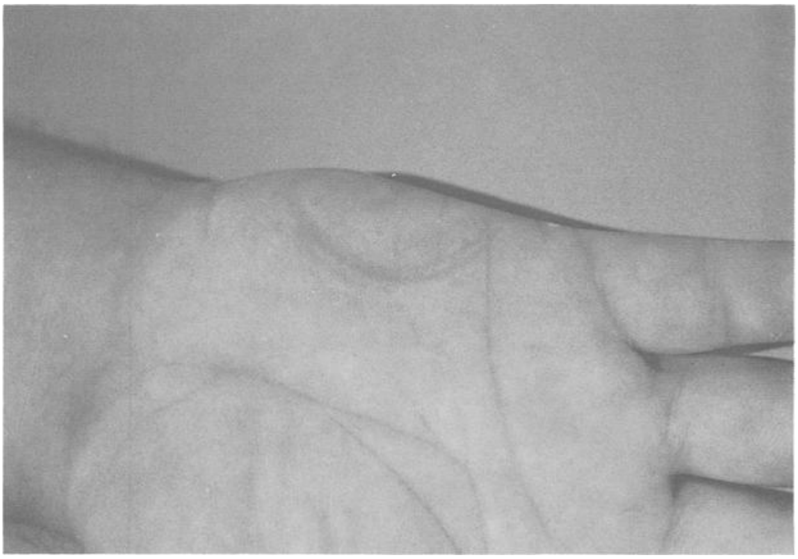

FIG. 5—*The patterned injury disclosed under alternative light illumination on the hand of a volunteer who struck an object with a galvanized pipe. A similar injury was discovered on the palm of the hand of a suspect in Case Three.*

the strap. Four days after the assault, a suspect was examined. An examination of the suspect's right hand with the light source revealed a pattern in the palm which matched the broken buckle. The buckle was placed in the investigator's hand and the pattern could be reproduced. The suspect had placed his foot upon the victim's face in order to increase his leverage in choking her. Figure 6 illustrates the patterned injury present on the face produced by the suspect's shoe sole. Although this pattern was discernible under normal illumination, the alternative light source provided a much more detailed photograph.

Case Five

A 20-year-old, black male was a suspect in a shooting death. The weapon was a single shot shotgun with a broken stock. Only the stock bolt extended beyond the receiver and was used as a pistol grip. Twenty four hours after the incident, when illuminated by the high intensity light, the pattern produced by the protruding bolt could be seen in the hand of the suspect.

Wound Pattern Duplication

Volunteers were selected to participate in a reconstruction of a beating using a galvanized water pipe. Color photographs of their hands were taken before any objects were struck. Both visible light and the high intensity alternative light source were used. The volunteers then struck a solid object with the pipe. An additional series of color photographs were then taken, again using both visible and alternative light illumination. Only under alternative lighting conditions could a pattern be duplicated similar to the pattern found in the hand of the suspect in Case Two above. A similar test was repeated with the knife in Case One and again a duplicate pattern could be reproduced. Although the patterns have been visualized in actual cases for as many as 10 days, additional simulation has shown that those patterns tend to persist for only a few hours. These are

FIG. 6A—*Photograph of the face of victim in Case Four.*

FIG. 6B—*The alternative light photograph of the same injury reveals much greater detail, contrast, and extent of the patterned injury.*

also dependent upon the degree of force that originally injured the tissue and much like bite marks, it is difficult to apply the same amount of force in the simulations.

Conclusion

This discovery has opened a new area of death investigation. Use of this technique to scan suspects who may have had contact with the weapon used to commit a crime may demonstrate patterned injuries. These injuries may have unique features that can link them to the weapon used in the crime. In turn this may assist the investigator in the elimination or concentration of effort to the correct individual and/or weapon early in the investigation.

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