TECHNICAL NOTE

PATHOLOGY/BIOLOGY

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Enhancing the Visibility of Injuries with Narrow-Banded Beams of Light within the Visible Light Spectrum

ABSTRACT: The use of narrow-banded visible light sources in improving the visibility of injuries has been hardly investigated, and studies examining the extent of this improvement are lacking. In this study, narrow-banded beams of light within the visible light spectrum were used to explore their ability in improving the visibility of external injuries. The beams of light were induced by four crime-lites® providing narrow-banded beams of light between 400 and 550 nm. The visibility of the injuries was assessed through specific long-pass filters supplied with the set of crime-lites®. Forty-three percent of the examined injuries improved in visibility by using the narrow-banded visible light. In addition, injuries were visualized that were not visible or just barely visible to the naked eye. The improvements in visibility were particularly marked with the use of crime-lites® “violet” and “blue” covering the spectrum between 400–430 and 430–470 nm. The simple noninvasive method showed a great potential contribution in injury examination.

KEYWORDS: forensic science, alternative light source, bruise, fluorescence, illumination, injury examination, narrow-banded visible light, pattern injuries, visibility, wound pattern

Adequate injury examination of victims of violence, both living and deceased, is essential for the reconstruction of a criminal event. The use of medical reports on the injuries as evidence in courts of justice demands an accurate description and interpretation of these injuries. Difficulties emerge when injuries lack in visibility, for example, due to wound healing mechanisms or a bruise in a transparent blue or yellow appearance. Furthermore, bruises that have been caused recently might not be visible at the surface of the skin yet. Improving the visibility of injuries that are not (evidently) visible to the naked eye would be a major advantage in gaining a complete documentation of a victim’s injuries.

The use of reflective ultraviolet (UV) radiation to improve the visibility of old wounds has been well documented (1–7), and also, the use of infrared (IR)-aided photography in this field has been explored (6–9). However, exposure to UV light is harmful, not only to the human skin and the eyes, but also to biological traces needed for DNA profiling. Another limitation is that the UV and IR spectrum consist of wavelengths, respectively, shorter and longer than the eye can detect, making it impossible to see a UV or IR radiation image of a wound. Such an image is only visible after photographic documentation with a filter blocking out all light passing through the lens except for the light of interest.

Visible light (400–800 nm) lacks these disadvantages and could therefore be more useful in improving the visibility of injuries. In addition, longer wavelengths penetrate the tissue deeper, which could enable the detection of hematoma in deeper tissue. When exposing the human skin to narrow-banded visible light, some light is reflected, some light is transmitted to deeper tissue layers, and some light is absorbed, resulting in fluorescence of the skin (10). Different components in the human skin and its biological building blocks have varying absorption and fluorescent curves (10). The compounds hemoglobin and its metabolite bilirubin present in traumatized tissue absorb light and are almost nonfluorescent. Consequently, the varying degrees of absorption and fluorescence of normal and traumatized skin enable the perception of an injury as a dark area within surrounding fluorescent skin.

Nevertheless, a limited number of studies have explored the use of the narrow-banded visible light method in improving the visibility of injuries (10,11). Studies examining the extent of the improvement are lacking. Therefore, we examined the usefulness of such a technique in injury examination. This was carried out by comparing the visibility of injuries of victims of violence during injury examination with the naked eye with their visibility during illumination with narrow-banded beams of light within the visible light spectrum. The beams of light were induced by crime-lites® (Mason Vactron Ltd, Worcestershire, UK), a set of four high-intensity LED light sources, each powered by a battery and providing a narrow-banded beam of light within the visible light spectrum. The crime-lites® are referred to as the crime-lites®

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“violet,” “blue,” “blue/green,” and “green.” The specific bandwidths of the light emitted by the crime-lites® are shown in Table 1.

### Methods

#### Population

This study has been conducted among a group of individuals visiting the Department of Forensic Medicine of the Public Health Service in Amsterdam (GGD Amsterdam) for injury examination. In the Netherlands, when a victim of physical violence notifies the police, an independent doctor conducts an examination. In Amsterdam, this takes place during consultation hours at the Department of Forensic Medicine. During the examination, a forensic physician notes a brief statement of the victim, examines the external lesions, and finally determines whether the injuries found match the given statement. This examination is documented in a form, which is added to the police record as evidence for further judicial proceedings. For medical attention, the victims are referred to their own general practitioner or specialist. Individuals visiting the GGD for injury examination between March and April 2009 were eligible to participate on voluntary basis in the study. The standard medical examination of injuries by the forensic doctor (intended for the formal documentation) was followed by the investigation with the crime-lites®. Oral informed consent for participation was obtained by the forensic doctor and the investigator.

#### Data Collection

Based on the standard medical examination by the forensic physician and additional questions by the investigator, both visible and potentially latent injuries were located.

The visibility of the injuries was initially categorized with the naked eye under standard lightning conditions present in the examination room (artificial light produced by TL lamps; further mentioned as TL light) using the following scale: no/bare/moderate/sufficient/good visibility. Subsequently, in a fully darkened room, the visibility of the injuries was assessed during illumination with the crime-lites® using the same rating scale. Essential to this technique is the perception of the injuries through a long-pass filter, designed to block the return of the excitation light and pass only the fluorescent light emitted by the tissues (10). This fluorescent light is always of a longer wavelength than the excitation light. Different filters were used that were supplied with the set of crime-lites®. The filters correspond to each crime-lite® and block excitation light beneath the wavelengths shown in Table 1 (cut-off wavelength).

A single investigator conducted the classifications with the naked eye and during crime-lite® illumination (RML). Furthermore, various characteristics were collected including victim’s age and sex and the type of injury. Injuries were photographed in TL light and during illumination with the crime-lite® that visually gave the best improvement in visibility.

#### Analysis

During the study period, a total of 82 injuries on 66 individuals were examined with the crime-lites®. All injuries were submitted by the investigator to a false-positive test to confirm the presence of an injury. The false-positive test was performed by pressing on the location of the (latent) injury as well as the surrounding skin. This test was also used when the presence of an injury was suspected during illumination with a crime-lite®, although no injury was visible to the naked eye. The presence of an injury was confirmed when the (latent) injury revealed a sensitivity, unlike the surrounding area. Nine injuries did not pass the false-positive test and were therefore excluded from further analysis. The visibility of 15 injuries with the naked eye was categorized as “good.” Therefore, the maximum score concerning visibility was already achieved during the observation with the naked eye, and these injuries were also excluded from the analysis.

The improvement, deterioration, or lack of change in visibility caused by the crime-lites® compared with the visibility with the naked eye was determined. An improvement or deterioration implies that the visibility with a crime-lite® differed one step or more on the rating scale compared with the visibility with the naked eye. In addition, we evaluated which crime-lite® showed the best improvement in visibility of the examined injuries. It was also determined which type of injury showed the most improvement in visibility due to the use of the crime-lites® compared with the naked eye. At last, photographs of injuries in TL light and during illumination with the crime-lites® were compared by a single investigator (RML).

#### Results and Discussion

##### Characteristics of Study Subjects

The analysis in this study is restricted to 63 injuries in 53 individuals. Approximately half of these individuals were female and the age of the subjects ranged from 12 to 56 years, with an average of 29 years. The age of the injuries varied from 0 to 12 days old, with an average of 2.6 days. The visibility of these injuries with the naked eye strongly varied: not visible \( n = 32 \) (51%), barely visible \( n = 17 \) (27%), moderate visible \( n = 6 \) (10%), and sufficient visible \( n = 8 \) (13%).

##### Effect of Crime-lites® on Visibility Injuries

Table 2 shows the changes in visibilities by each of the four crime-lites®. During the excitation of the crime-lites® “violet”

<table>
<thead>
<tr>
<th>Crime-lite®</th>
<th>Bandwidth (nm)</th>
<th>Decline (%)</th>
<th>No Change (%)</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violet</td>
<td>400–430</td>
<td>5 (8)</td>
<td>40 (62)</td>
<td>35 (56)</td>
</tr>
<tr>
<td>Blue</td>
<td>430–470</td>
<td>6 (9)</td>
<td>36 (57)</td>
<td>20 (32)</td>
</tr>
<tr>
<td>Blue/green</td>
<td>460–510</td>
<td>9 (14)</td>
<td>30 (47)</td>
<td>22 (35)</td>
</tr>
<tr>
<td>Green®</td>
<td>500–550</td>
<td>10 (16)</td>
<td>25 (40)</td>
<td>15 (24)</td>
</tr>
</tbody>
</table>

*Due to lack of results with the crime-lites® “blue/green” and “green,” these crime-lites® were omitted halfway through the research; therefore, fewer injuries were examined with these crime-lites®.

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**TABLE 1—Specification of crime-lite® bandwidths and cutoff wavelengths of the corresponding filters.**

<table>
<thead>
<tr>
<th>Crime-lite®</th>
<th>Bandwidth (nm)</th>
<th>Cut-off Wavelength Filter (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violet®</td>
<td>(400–430)</td>
<td>435</td>
</tr>
<tr>
<td>Blue®</td>
<td>(430–470)</td>
<td>476</td>
</tr>
<tr>
<td>Blue/green®</td>
<td>(460–510)</td>
<td>529</td>
</tr>
<tr>
<td>Green®</td>
<td>(500–550)</td>
<td>549</td>
</tr>
</tbody>
</table>

**TABLE 2—Changes in visibility of injuries of physical violence victims by each of the four crime-lites® compared with their visibility to the naked eye (n = 63).**
TABLE 3—Visibly improved injuries of physical violence victims by the crime-lites® compared with their visibility to the naked eye—(n = 27).

<table>
<thead>
<tr>
<th>Rated Visibility With the Naked Eye</th>
<th>Visibly Improved Injuries (n = 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best Improvement by Crime-Lite® “Violet” (%)</td>
</tr>
<tr>
<td>Not</td>
<td>1 (20)</td>
</tr>
<tr>
<td>Barely</td>
<td>2 (40)</td>
</tr>
<tr>
<td>Moderate</td>
<td>1 (20)</td>
</tr>
<tr>
<td>Sufficient</td>
<td>1 (20)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (100)</td>
</tr>
</tbody>
</table>

and “blue,” most of the injuries showed an improved visibility (respectively, 32% and 35%) rather than a decline (respectively, 13% and 8%). In contrast, the crime-lites® “blue/green” and “green” showed more deterioration in the visibility of injuries (respectively, 19% and 41%) than improvement in visibility (respectively, 6% and 3%). Taken together, approximately 43% (n = 27) of all examined injuries showed an improvement in visibility when exposed to a crime-lite® and the perception through its corresponding filter. These visibly improved injuries are hematomas (n = 11) (including red/blue- and yellow-colored bruises), red discolorations (n = 7), pain but no visible injury (n = 4), abrasion (n = 4), and swelling (n = 1).

Concerning all visibly improved injuries, 26% (n = 7) was equally improved using either the “violet” or “blue” crime-lite®. Only 19% (n = 5) gained the most improvement in visibility with the crime-lite® “violet” and 56% (n = 15) with the crime-lite® “blue.” In some cases, the “blue/green” and “green” crime-lites® showed an improvement in visibility of the injury. However, the visibility of these injuries was improved to a greater extent by the “violet” and/or “blue” crime-lites®. The crime-lites® “violet” and “blue” outperformed the crime-lites® “blue/green” and “green.”

The discoloration of the skin due to a hematoma contains the biological components hemoglobin and its breakdown product bilirubin. The absorption peaks of hemoglobin within the range of the crime-lites® are between 414–422 nm and at 543 nm, whereas the absorption peak of bilirubin is at 460 nm (12,13). The crime-lites® “violet” and “blue” cover the light spectrum between 400 and 470 nm, thus including the absorption peaks of both hemoglobin and bilirubin. Despite the hemoglobin’s absorption peak at 543 nm, a wavelength in the range of the crime-lite® “green” (500–550 nm), this crime-lite® showed an inadequate performance as well as the crime-lite® “blue/green.”

The limited discriminatory power could be attributed to the stronger absorption by hemoglobin at 414–422 nm compared with its absorption at 543 nm (13). Based on our findings, an examination of injuries with the crime-lites® can be restricted to the crime-lites® “violet” and “blue.”

Type of Injury Showing the Most Improvement in Visibility

Table 3 demonstrates to which category (not/barely/moderate/sufficient) the visibly improved injuries were assigned during the naked eye assessment. Especially, those injuries that were categorized as barely visible with the naked eye showed an improved visibility when illuminated by a crime-lite®. Of the 27 injuries showing improvement, more than half of the injuries were categorized as “not visible” or “barely visible” with the naked eye (respectively, 15% and 44%). An example is shown in Fig. 1. As more than a quarter of the total injuries examined (n = 63) were barely visible with the naked eye, this result indicates crime-lites® have a great contribution to make in injury examination.

As a result of crime-lite® illumination, four of 32 latent injuries (13%) became visible. Within fluorescent (insensitive) skin, a dark (and sensitive) area was observed (see Figs 2 and 3). Before illumination, these injuries were rated as “not visible” to the naked eye. A possible reason the majority of latent injuries not being visualized is twofold. First of all, the injuries may be hematomas in the deeper tissue and therefore are likely to remain undetected. Second, the injuries may concern traumata that theoretically cannot be visualized with the crime-lites®, for

FIG. 1—Yellow hematoma, (left) in TL light, (right) illuminated by the crime-lite® “violet.”

FIG. 2—Latent injury, (left) in TL light, (right) illuminated by the crime-lite® “violet.”
example, myalgia. Although the number of latent injuries being visualized is limited, the possibility in doing so can be of value in certain cases of injury examination.

Further Findings

Photographic documentation showed that due to the crime-lites® “violet” and “blue,” a yellow color in a hematoma or transparent blue parts of a hematoma became more visible in the form of darkened spots (see Figs 4 and 5). Transparent blue and yellow parts of a hematoma were barely perceptible with the naked eye. Thereby, the crime-lites® visualized more surface of a hematoma (and hence the contours) than with the naked eye. The photographs of injuries also showed that the patterns in injuries became more discernable with the crime-lites® (see Fig. 5). Photographic documentation of the injuries during crime-lite® illumination is useful when wishing to observe the subtle features of an injury. Moreover, it must be noted that objective photographic documentation will be essential when using the crime-lite® observation as evidence in a criminal trial. Except type of injury, additional characteristics of the examined injuries including its location, cause, and date/time of infliction and skin type according to Fitzpatrick classification (14) (1 “very light,” 2 “light,” 3 “light intermediate,” 4 “dark intermediate,” 5 “dark,” 6 “very dark”) were registered. However, the current sample size has to be extended to draw well-based conclusions with respect to the influence of these variables on crime-lite® examination of injuries.

Conclusion

In conclusion, narrow-banded beams of light within the visible light spectrum enhance visualization of injuries, including contours, size, and pattern. Crime-lites®, especially “violet” and “blue,” particularly improve the visibility of injuries that are barely visible to the naked eye. Crime-lites® also permit visualization of injuries that are not otherwise visible to the naked eye or were not noticed prior to the crime-lite® examination. Therefore, crime-lites® contribute to a more encompassing image of the injuries of victims of violence. This allows a more complete comparison of scenarios of injury causation with a victim’s clinical presentation. The technique is noninvasive, quick, and easily performed, without interference of the examined injury or the disturbance of trace evidence. The method shows a great potential contribution to injury examination.

References


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