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Detection of Firearms Imprints on Hands of Suspects: Study of the PDT-Based Field Test

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ABSTRACT: The results of a multifaceted research project towards the optimization of the visualization process of firearms contact marks on hands are reported. Latent imprints that are formed by the close contact between the metallic parts of the weapons and the palms were visualized by the application of the PDT iron (II) reagent. Various factors affecting the quality of the marks were studied. Also PDT analogues were synthesized and their performance compared with that of the original compound.

Some of the analogues show slight advantages over PDT in contrast and sensitivity, but PDT in acetone solution, such as in the commercial preparations Ferroprint or Ferrotrace seems to be the formulation of choice for reasons of availability and cost. It can visualize latent firearms impressions on the hands several hours after the contact.

KEYWORDS: forensic science, field tests, criminalistics, latent imprints, firearms, 3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine, Ferrorprint, Ferrotrace

While investigating crimes involving the handling or use of firearms, it would be of great advantage if imprints of the weapons could be developed on the hand of the suspect, regardless of whether the gun had been fired. The technique used in the early 1970s was spraying the hands of the suspect with a solution of Fe (III) reagent—0.2% 8-hydroxyquinoline ("oxine test") in isopropanol and observing the sprayed area under ultraviolet light (1). Implementation of this technique may disclose the presence of metallic residues on the hands of a suspect in a pattern attributable to contact with specific types of handguns or tools. One must be familiar and experienced with the patterns characteristically produced on the hands by as many different weapons as possible. It is far better, whenever possible, to have the actual weapon involved available in order to directly compare any patterns observed on the suspect and the pattern known to result from the handling of that particular weapon. However, the oxine reagent has several disadvantages: 1. It is not specific to iron since it forms fluorescent metal chelates with many other metal ions, e.g., Mg, Ca, Ni, Al and Cu (2). From the authors' experience, hands wetted by tap water, which contains Mg and Ca ions, will give a fluorescent color reaction, 2. Low stability of the reagent—it has to be prepared directly before use, 3. The oxine reagent has a highly unpleasant smell, making its use unbearable in a closed space, and 4. The ultraviolet fluorescent photography which must be employed, often causes complications.

In 1976, Goldman and Thornton suggested the application of a more useful reagent, PDT (3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine) (compound 1, Fig. 1), that forms a magenta complex even with submicrogram levels of iron on hands of firearms holders, without the need for ultraviolet fluorescent photography (3). This reagent was found by the authors to be comparable in sensitivity to 8-hydroxyquinoline. But their water soluble formulation, or even its improved version (4) was not adequately sensitive in actual cases. Trials in this laboratory have shown that if the chemical reaction took place an hour or more after the contact, no visible reaction occurred (5).

It was found in this laboratory that the addition of small amounts of mild reducing agents such as ascorbic acid to the PDT formulation considerably improved the imprints detectability even after several hours (5). Similar results, though on fresh contact marks only, were reported independently by C.W. Lee from the Hong Kong Police Department (6). This new formulation, which was then renamed "Ferroprint," has been in operational use in the Israel Police since 1980 (7).[2]

It seems, however, that quite often the quality of the resulting pattern is poor or there is still no color development even in cases of confirmed recent contact with a weapon. This may result from too brief a contact with the weapon and hence too small an amount of iron transferred to the hand, the good condition of the weapon (no rust) or not enough perspiration. Other factors that may interfere with the effectiveness of the PDT reaction are flimsy contact with the firearm, a long time lapse since the contact and various activities with the hands after the contact and before the application of PDT. Also, the butt of at least one handgun (Glock), is made entirely from plastic, with no metallic parts.

Our study of the full potential of the PDT reaction was divided into three parts. In the first part, we tried to estimate the influence of time lapse and various activities—particularly hand-washing—on the PDT reaction. In the second part, we studied the feasibility of transferring the metal traces onto an adhesive plastic sheet before color development. In the third part of this project, 16 new analogues of PDT were synthesized and their sensitivity toward iron (II) in solution (8) and on hands was compared with that of PDT. Out of the 16 compounds, two were chosen for this study. These were 3-(4-phenyl-2-pyridyl)-5,6-bis-(3,4-dimethoxyphenyl)-1,2,4-triazine (PPDT, compound 2, Fig. 1) and 3-(1-isoquinolyl)-5,6-bis-(3,4-dimethoxyphenyl)-1,2,4-triazine (IDT, compound 3, Fig. 1). Compound 2 exhibited the highest sensitivity

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[2]Two devices, in the form of spray cans, which are based on the PDT-ascorbic acid formulation, are commercially available. These are Ferroprint, by Sulamith Ltd., Hod Hasharon, POB 170, Israel and Ferrotrace,

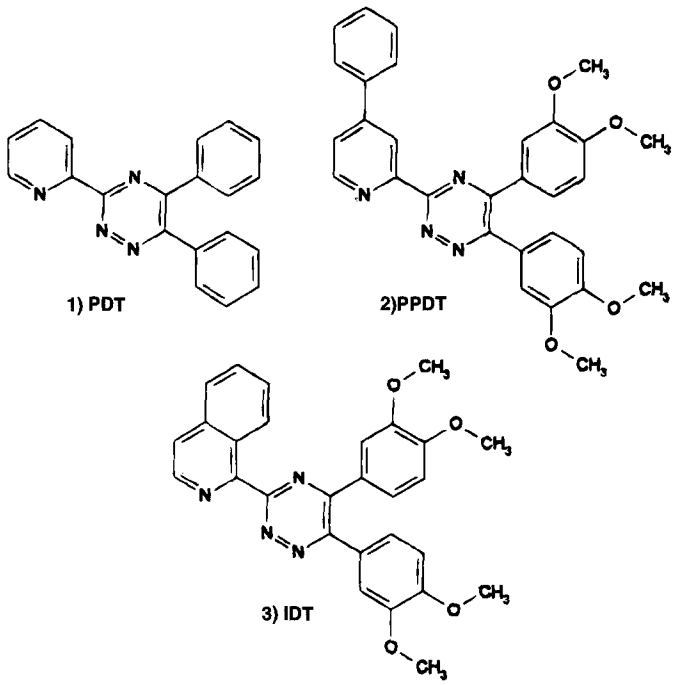


FIG. 1—*PDT and two of its analogues, PPDT and IDT, that were examined in this study.*

toward iron (II) in solution (ϵ-the molar absorptivity, 3.81×10^4 1 mol^{-1} cm^{-1} at 571 nm, compared with 2.43×10^4 for PDT at 555 nm (8)). Compound 3 gave the iron (II) complex with the most desirable color (olive green) in contrast to skin color, also with a pretty high sensitivity in solution ($\epsilon - 3.47 \times 10^4$ at 594 nm (8)).

Experimental

The reagents used in this study were the following: PDT-ascorbic acid formulation was used from the commercial spray cans, Ferroprint or Ferrotrace, which contain 0.1% PDT in acetone solution. For the experiments with PDT without reducing agent, a 0.1% solution of PDT (Aldrich Chemicals Co. Inc.) in acetone was prepared.

The two new PDT analogues, PPDT and IDT, were synthesized analogously to Stephen and Islam (9). Their properties were described by us lately (8). Working solutions were prepared as follows: to a 100 mL 0.1% solution of the compound in acetone, 0.2 mL of saturated aqueous solution of ascorbic acid was added. The solutions were applied from a TLC spray can. White adhesive lifter with protective cover, by ISA Ltd., Creasley Street, Bulwell, Nottingham, England (Industrial Self Adhesives) was employed.

A used Spanish Star 9 mm pistol was used as a model for this series of experiments, due to its pronounced steel profile (Fig. 2). It was held firmly in the hand of one of us (B.G.) for three minutes.[3] Other pistols and breaking tools such as a wrench were tested occasionally, just to realize the generality of the phenomenon. They also produced well defined marks.

by Erez Forensic Technology Ltd., POB 35008, Jerusalem 91350, Israel. Their performance is quite similar.

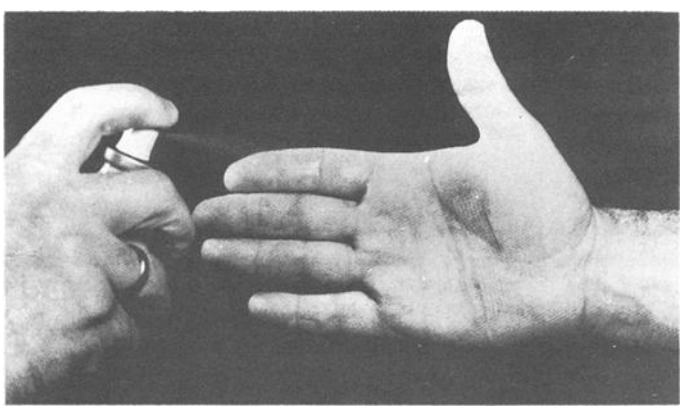
[3]Three minutes holding time may be unrealistic under real conditions of crime perpetration, but it was decided as an optimal experimental time condition, under the premise that marks that do not develop within three minutes will not develop at all.

FIG. 2—*Spanish Star pistol showing its pronounced steel profile.*

The efficiency of the three reagents was examined in two ways, direct spraying on the hand (Fig. 3) or on the adhesive sheet. The transfer process was carried out by pressing the hand horizontally for a few seconds onto the adhesive sheet. The quality of the developed impressions was determined by visual examination. Normally, the hand would be divided into two. One half was developed with the new reagent while the other half was developed with PDT (Ferroprint or Ferrotrace) for comparison (Fig. 4).

The pistol was held for 3 min and the hand was sprayed with the reagents at various intervals: immediately after the contact, and one, two, four and seven hours after the contact. In the meantime, the hands were involved in regular office activity, but without washing them. The same series was carried out after transferring the latent impressions to adhesive paper. The transfer was done at the same time intervals as above, and both the hand and the adhesive lifter were sprayed with the reagents.

The pistol was held for 3 min. The hand was sprayed with the regular PDT reagent (Ferroprint, containing ascorbic acid) and with PDT solution 0.1% in acetone, not containing the reducing agent, at the following time intervals after the contact: immediately, 1 h and 2 h. The pistol was held for 3 min. The hands were washed



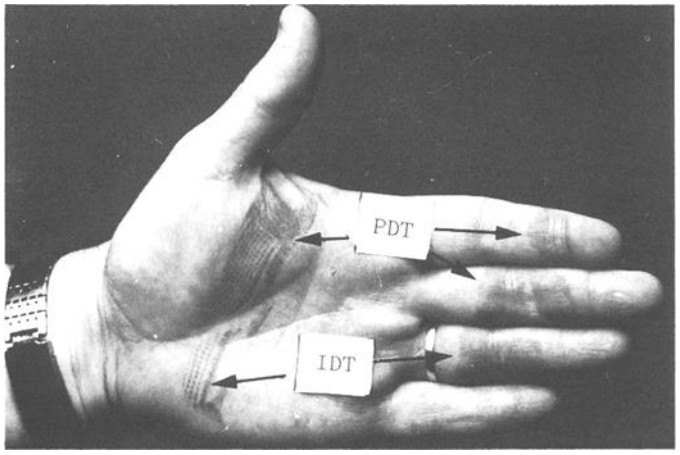


FIG. 4—*Two halves of the hand—one half sprayed with the PDT analogue, IDT, and the other half with Ferroprint.*

with tap water (lukewarm) and soap and dried with a cotton towel. This was done at the following time intervals from the contact: immediately, and 1, 2, and 4h. PDT (Ferroprint) was applied to the hand directly after washing. All experiments were conducted at least two times which produced similar results.

Results

The efficiency of the PDT analogues was examined. Both compounds, PPDT and IDT developed the imprints of the iron parts very similarly to PDT. This observation refers to direct spraying on the hand and processing the adhesive lifter after transfer. While impressions developed by PPDT had a color quite similar to that obtained by PDT, the impressions obtained by IDT were nearly black, and showed slightly better contrast on the skin.

The following results were observed regarding the influence of different time intervals: (a) *With direct spray on the skin*: well defined impressions could be developed even seven hours after the contact. In this series, no attempt was made to develop the marks after longer periods after contact. (b) *With transfer to adhesive lifter* and spraying both the hand and the plastic sheet at these intervals: (1) Immediately after the contact: strong mark on the adhesive sheet and weak reaction on the hand was observed. (2) One hour from contact: weak reaction on the adhesive sheet and strong mark on the hand was observed, and (3) Two hours from contact: no reaction on the adhesive sheet and strong mark on the hand was observed.

The influence of ascorbic acid with time was demonstrated by the following: (a) Immediately after contact: strong marks were obtained by PDT with or without ascorbic acid. (b) One hour from contact: no reaction without ascorbic acid. Ferroprint (PDT with ascorbic acid) developed strong marks, similar to those obtained with fresh impressions. The influence of washing hands was demonstrated by: (a) Washing the hands right after the contact: no visible impressions are obtained after application of Ferroprint and hence no traces of iron are left on the hand after the wash. (b) Washing the hands two hours from contact: strong marks are developed with Ferroprint.

Other Phenomena That Were Observed Throughout This Series

Occasionally the color development is not instant and the impression reaches maximum intensity after 2 or 3 min. Spraying the hands with water or even washing them under the tap *after* PDT application, accelerates the color development without blurring the marks.

Discussion

The impressions of firearms that are reported in this work have been obtained under more or less ideal conditions. In actual cases, the contact may be shorter, the grip not as firm, the weapon may move in the hand and it may be in excellent condition (no rust). The authors' aim was to study the potential of the PDT reaction.

Visualization of latent impressions that are left on the hand by holding a weapon (or other tools) by the PDT method is based on the formation of a highly colored complex between the reagent and traces of iron which are transferred to the hand during the contact. Only divalent iron (ferrous form, Fe II) reacts in this way (Fig. 5). Trivalent iron (ferric form, Fe III) gives no color reaction with PDT (3–5,6,8,9). It is not clear, at this point, whether the iron traces which are originally transferred from the weapon to the hand are metallic iron, rust (a combination of di- and trivalent iron oxides (Fe II and Fe III)) or both. The experimental data clearly shows that right after the contact there is a considerable concentration of iron II on the hand and hence the strong contact mark which is obtained with PDT, even without reducing agent.

The lack of PDT reaction in the absence of ascorbic acid 1 h after the contact and the strong reaction in the presence of ascorbic acid indicate the quick oxidation of Fe II to Fe III on the hand, a process which is practically completed in less than an hour. Thus, the reducing agent is essential if the reaction is to take place more than a few minutes after the contact (and not only to reduce the trivalent iron which is originally present there, from the rust, as suggested by Lee (6)). The iron ions from the deposits on the hand probably migrate in time into the skin or they may form strong chemical bonds with the biological material. This is indicated by the development of strong impressions with Ferroprint on washing the hand one hour or more after contact, in contrast to the failure of obtaining impressions when the hand is washed immediately after contact. This assumption is supported also by the following observations: (a) Good transfer of iron to the adhesive lifter immediately after contact and hence a strong mark is obtained on the sheet and a weak one on the hand, (b) One hour from contact there is only a partial transfer to the adhesive lifter: a weak mark on the sheet and a strong one on the hand, and (c) Two hours from contact there is no transfer to the adhesive lifter but a strong mark develops on the hand.

Regarding the potential of the PDT analogues: even though the two new compounds, IDT and PPDT, showed higher reactivity

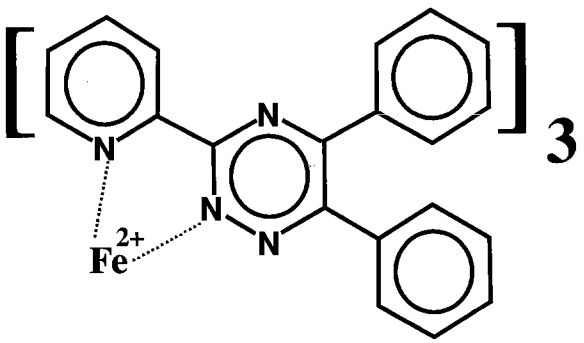


FIG. 5—*Structure of the PDT complex with ferrous (iron II) ions.*

than PDT, in our opinion, the differences in sensitivity and contrast seem, at this point, too small to justify the costly production of these compounds which, unlike PDT, are not commercially available yet.

Several precautions are necessary when one is utilizing the developed pattern on the hand of a suspect to provide evidence. All methods for delineating patterns of iron residues on hands resulting from the handling of weapons or tools, irrespective of the chemical reagents used to visualize them, have inherent limitations that must be recognized and understood. First the object held must have a distinctive or characteristic morphology and the pattern produced on the skin must reflect this if this is to be used as associative evidence. Several factors can adversely affect the fidelity of the pattern. In the more commonly encountered situation where there is a reaction but where the pattern is less distinct, the results may be useful, but only as investigative aids. If the circumstances are favorable and the results are to be used as associative evidence, it is important that they be documented photographically so that they can be evaluated independently later.

Conclusions and Recommendations

The commercial pre-packaged aerosol devices, Ferrorprint and Ferrotrace, which contain a solution of PDT and ascorbic acid, provide good means to link between suspect and weapon by developing the iron imprints on the hand. To the best of our knowledge, no other devices of this kind are available on the market. Both preparations belong to the "forensic field tests" category whose aim is to guide the investigators. The developed impressions may become evidence, but comparison between the impression patterns and suspected objects must be done and interpreted in the laboratory by experienced examiners (1,7).

Ferrorprint and Ferrotrace can detect firearms imprints on hands seven hours (and maybe more) after the contact, provided that the hands have not been washed right after the contact. The recommended procedure to use these preparations is to spray the hands from ca. 15 cm. (Fig. 3). If a mark does not develop within two minutes, the hand can be sprayed or washed with water, which may accelerate the appearance of the magenta color and intensify the mark. The hands with the marks are then photographed. If gun-shot residue (GSR) is to be collected also, by the adhesive-lift method, it must precede the Ferroprint test. GSR collection always before Ferroprint!

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