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Forensic Science Does Not Start in the Lab: The Concept of Diagnostic Field Tests*

ABSTRACT: An attempt to improve an analytical system can focus either on the actual processing or on the input. In forensic science, much emphasis has been placed on improving laboratory procedures, as though the input is already the best that can be obtained. Means of improving the basic input have gained much less attention. Yet, it must be agreed that even the best laboratory cannot gain from an item more than has been contained in it when it arrived from the field. The detection of latent materials at the crime scene by physical or chemical techniques and the diagnostic examination of material already discovered belong to the concept of diagnostic field tests. This group also includes "mapping" for the presence of certain materials, such as latent fingerprints through the distribution of amino acids on the surface. These tests are conducted outside the laboratory, without sophisticated instrumentation, at the crime scene, the suspect's home, or elsewhere. A significant advantage of the use of diagnostic field tests is the ability to deal with "dissipating evidence" such as gunshot residue or explosive traces on the hands of suspects. If time is lost, there is a risk of losing such evidence, which is liable to deteriorate rapidly. In my presentation, I will discuss older and some newly developed forensic field tests, with specific emphasis on the Israeli experience.

KEYWORDS: forensic science, field tests, BTK, ETK, ferrotrace, PET, Lucas medal, Joseph Almog

I would like to open my presentation by thanking the American Academy of Forensic Sciences, its Board of Directors, and the Awards Committee for granting me the Lucas Medal, one of the most prestigious awards in the world of forensic science. Last year, two Israeli scientists were awarded, for the first time, the Nobel Prize in Chemistry, something we considered close to impossible due to inferiority in working conditions and resources, which is particularly important in the experimental sciences. I am deeply moved and proud to be the first Israeli to receive one of the most important international awards in forensic science. I attribute this achievement, first and foremost, to the excellent team work in forensic science research in Israel, between law-enforcement agencies and academic institutions. It also reflects on the fact that we have realized long ago, that there is no real justice without forensic science, or, as phrased in 1983 by Dr. Ford, Erie County Chief of Police, in a personal letter to Meyer Kaplan, Head of the Israel Police Criminal Identification Division: "It is getting to the point where hard, physical evidence is about all a prosecutor can hang his hat on . . ."

In academic activity, scientists express themselves by publishing their findings in professional journals. This leads to national and international recognition, which means research funds and invitations to lecture. Some of these ideas may find a broader scope than just pure science: the development of new medications, advanced instruments, materials with special properties, and sometimes even theoretical essays. Since 1974, when I made the decision to leave academic life for pioneering work in forensic science, I have been frequently asked what brought a young scientist, working at the "Academic Olympus," MIT in this case, to jump to the cold and murky water of police life. Well, in retrospect, I can decisively say that very few things are as rewarding to a scientist as the ability to resolve a high-profile crime by scientific methods.

As you can see, I chose to speak today on field tests, a subject that in my opinion does not receive sufficient attention from the forensic science community. One of the main reasons being that many crime laboratories do not consider it an integral part of their work. In many law enforcement agencies, it is assumed that the central laboratory ought to analyze exhibits that arrive from the field, whereas the investigation units, normally without a scientific nucleus, ought to take care of the work at the crime scene.

The need for significant improvement in crime scene technologies has been recognized long ago by the National Institute of Justice. Let me quote from their 1999 report on the status and needs of forensic science (1). This chapter deals with *Crime scene response and related examinations*:

> . . . The forensic aspects of crime scene response have not received adequate attention or funding. This needs to be remedied in a timely manner because the quality of evidence recognition, documentation, collection, and preservation are critical to the quality of results from resultant analyses . . .
>
> . . . The methods used in crime scene response and related endeavors are quite diverse and should logically correspond to each individual case and the specific types of evidence recovered.

Among the specific needs in this area, the report mentions small, rugged, chemical analysis instruments for onsite preliminary or confirmatory analysis in investigations involving drugs, explosives, and hazardous materials, the rationale being

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that "Current methods for presumptive testing of materials at the scene do not allow for the preliminary detection of the full complement of substances for which such testing is important. For drugs and explosives, these portable methods significantly enhance the productivity of the investigative/forensic science interface, because the materials forwarded from field investigations are more routinely verified in the laboratory than when no screening is available. The potentially wide distribution of explosive residues in a postblast scene demands rapid localization of the areas and particular items of evidence bearing such traces, so that the investigation can be suitably focused to avoid the deleterious effects of weather and human activity."

The following example is a low-profile case, involving a shoeprint examination. It demonstrates, however, the importance of the two links: work at the scene and complementary laboratory work. We found that invisible shoe-prints contain traces of dust, which is characterized by a slightly alkaline chemical reaction. Thus, a two-stage process was developed in which the latent prints are first "lifted" from the scene, by adhesive tape or by electrostatic means, and are transferred to the laboratory for chemical enhancement by the pH reagent bromophenol blue (BPB) (2). In this recent burglary investigation, the crime scene officer noticed a very faint shoeprint on a closet. After photographing the mark, he carefully lifted it with an adhesive tape and sent it to the lab for processing. Treatment with the BPB reagent enhanced the print (Fig. 1) to a degree that enabled connection of the suspect's shoe with the crime scene (3).

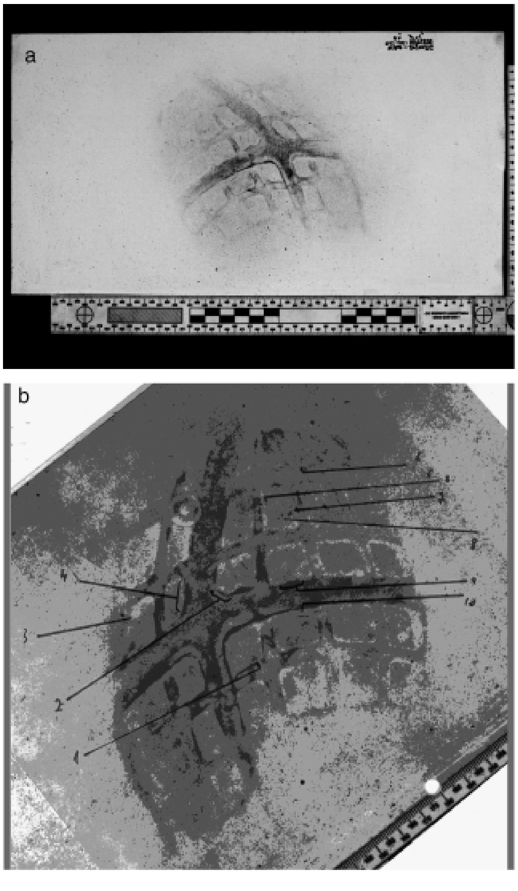

FIG. 1—*Shoeprint enhancement by the bromophenol blue (BPB) reagent: (A) before chemical treatment, and (B) after application of BPB. The numbered lines mark matches with suspect's shoe. (Courtesy: Toolmarks and Materials Lab, DIFS.)*

Forensic field tests are diagnostic examinations for forensic purposes. Their aim is to guide the investigator. They may become evidence after they have been confirmed by the laboratory.

In the early 1980s, we developed a field test for traces of military explosives. It improved significantly our ability to cope with the growing problem of explosive materials used by criminals and terrorists. The Explosives Testing Kit (ETK) (Fig. 2) could detect traces of military explosives on the hands of suspects as well as distinguish between explosive and nonexplosive materials (4–6). There has been a case in which traces of the notorious plastic explosive Semtex were detected on a youngster suspected of planting an improvised bomb on a crowded beach. The bomb, disguised as a packet of cigarettes, had been carried to the scene under his swimsuit, leaving sufficient traces on his stomach to be detected at the scene by ETK (Fig. 3). In a top-security prison in Northern Ireland, ETK was also used to detect traces of plastic explosive after other, more sophisticated devices had failed. It led to the discovery of 2.5 kg of the same explosive, Semtex, hidden in one of the cells.

The appearance of urea nitrate, a powerful homemade explosive, in our arena (Fig. 4) has led us to the recent development of UN-1, another field test for the characterization of traces of this material (Fig. 5). Police Explosive Ordinance Disposal units and the Explosives Identification Lab are already using it in their daily work (7). Incidentally, urea nitrate was the explosive that was used in the first terror attack on the World Trade Center in New York in February 1993 (8).

Professor Keinan of the Technion in Haifa has recently developed a slightly more sophisticated field device for the diagnostic examination of another notorious homemade explosive, TATP (Fig. 6). This extremely sensitive substance, used either as a detonator or as the major charge in terrorists' improvised bombs, caused the loss of hundreds of lives in Israel and in other countries (9–12). TATP was also found in Richard Reid's, the "Shoebomber's" shoes (Fig. 7) (13) and, to the best of my knowledge, also in the recent London bombings (14). Now, even tiny traces

FIG. 2—*Explosives Testing Kit (ETK). Each one of the colored tubes detects a different family of explosives.*

FIG. 3—*Explosive Testing Kit testing for explosives traces on suspect's stomach. Left: sampling and right: positive response for nitrate and nitramine-type explosives.*

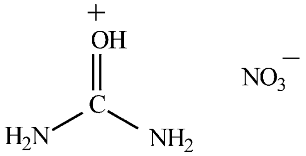

FIG. 4—*Structure of urea nitrate (7).*

of TATP can be readily diagnosed by Keinan's "Smart Pet" (Fig. 8) (15).

Perhaps less known, but quite useful in Israel is the field test for bullet holes, or Bullet-hole Testing Kit (BTK). This simple test, originally suggested by Steinberg et al., (16) helps in deciding whether holes in walls, cars, or fabrics have been caused by bullets or by other sharp objects. It is based on the detection of the distribution of traces of copper and lead around the hole. In the following case, its application was essential in concluding that the death of a lorry driver was a suicide or accident but not a terrorist act. A soldier driving a military lorry was found dead in the lorry's cab after a shot had been heard. Bullet holes were found in his head and in the windscreen (Fig. 9*A*). Large military forces immediately surrounded the area, assuming this was a terrorist attack. It became essential to determine quickly whether the shot had been fired from outside, indicating terrorist activity, or inside the cab, indicating accident or suicide. BTK was applied. Even an untrained eye could easily see that the concentration of lead is much higher on the inner side of the windscreen (Fig. 9*B*). The army was instantly stood down.

FIG. 5—*UN-1 color test for traces of urea nitrate (7). Left button: negative, and right button: positive response.*

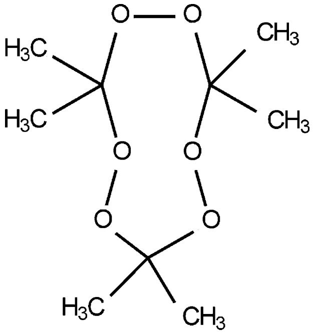

FIG. 6—*Structure of TATP (9).*

In the January 2005 issue of AAFS Academy News, Dr. John De Haan, a leading American criminalist, writes that a typical reaction from young criminalists to the suggestion of applying new techniques is: *"If it is not an ASTM test, I can't use it."* And John comments: *"I would hate to think of all the connections I made in thirty-plus years that would not have been made if the only tools I could use were ASTM methods . . ."* Many field tests fall under this description; they are not official ASTM methods, but they can make an essential contribution to crime analysis.

FIG. 7—*Richard Reid and his TATP–containing shoe (13).*

FIG. 8—*Keinan's PET for detection of peroxide explosives (15).*

The appropriate use of forensic field tests has several advantages:

a. they do not require scientists,
b. they can be conducted everywhere,
c. they can be applied before the evidence has deteriorated,
d. they are relatively inexpensive, and,
e. they enable the elimination of a large number of suspects in a short time.

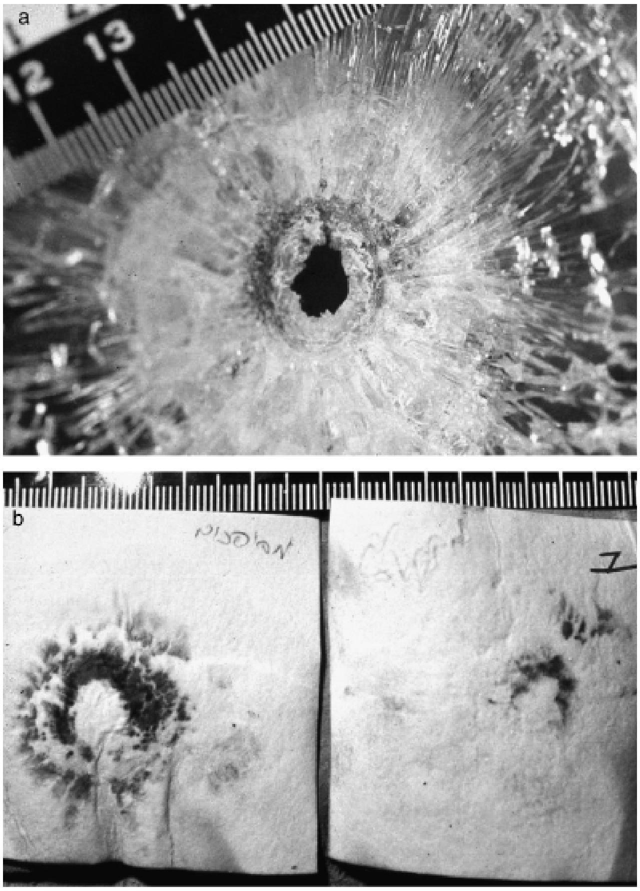

FIG. 9—*Resolving a suspected terrorist incident by the Bullet-hole Testing Kit: (A) vehicle's windscreen, (B) lifts from the windscreen; lead distribution around the hole. Inner side (left) and outer side (right). (Courtesy: Mobile Laboratory for Serious Crime Scenes, DIFS.)*

I must emphasize that I am not trying to convince you that field tests should replace laboratory examinations. On the contrary; wherever possible, laboratory tests must be conducted. After all, they are much more accurate, much more sensitive and versatile, and they cover a much wider scope. There are circumstances, however, under which the application of an appropriate field test could determine between the success and failure of resolving a crime.

The main disadvantage of forensic field tests is that they are nonspecific (color tests, for instance), thus always requiring laboratory confirmation. The nonspecificity was expressed in the wrongful conviction of the "Birmingham six" in 1974, where six innocent people were convicted of planting lethal bombs in two Birmingham pubs. The conviction was based on a positive color reaction on their palms, which could indicate traces of gelignite, but other innocent materials could also produce a similar color (17).

For sometime now, we have been investigating techniques for visualizing firearms' impressions on the hands of recent holders. In police investigations involving shootings, the question that arises is whether a specific suspect has handled a particular weapon. In some cases, the answer to that question can be instrumental in determining the direction of the entire investigation. Almost 30 years ago, Thornton and colleagues (18,19), from UC Berkeley, suggested using 3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine (PDT) reagent for mapping iron traces on the palms of a firearm holder. His brilliant idea suffered from one serious drawback: it was effective for only a few minutes after the contact, which is impractical in actual crime investigations. Thornton's technique has been significantly improved, almost simultaneously, by two groups of researchers: C. W. Lee in Hong Kong and our group in Israel (20–23). The improved test, which is in constant use by our crime scene officers, is produced in Israel under the name Ferrotrace. The result can be observed by the appearance of a violet–magenta stain, which, in many cases, has the shape of the metallic parts of the weapon. Hand grenades or burglary tools may also leave such marks, as well as innocent, iron-made items. Firearms' impressions may develop not only on the palms but also on the hips or on the back (Fig. 10). Under laboratory conditions, Ferrotrace developed meaningful impressions up to 24 h after holding a weapon.

The theme of our present conference is "Justice through Science." Perhaps the most important expression of this slogan is the ability of the forensic scientist to "turn the tide" or reverse the investigator's initial perceptions. In their famous research report "*Convicted by Juries, Exonerated by Science*" Connors et al. (24) discuss the use of DNA evidence to establish innocence after trial. They present 28 examples of individuals released from prison because of DNA testing. I wish to demonstrate that not only sophisticated laboratory techniques such as DNA testing can exonerate the innocent, but that also relatively simple field tests could also contribute to the administration of justice by reversing the initial perception.

In a search for a young successful model and her boyfriend, the police arrived at a Jerusalem apartment where they had been living. The door was locked and the telephone calls went unanswered. The boyfriend's brother forced entry through a porch door and let the police in. They found the dead bodies of the couple. A loaded gun was found next to the girl's

FIG. 10—*Detecting recent contact with firearms by Ferrotrace: (A) by holding a gun firmly, microscopic amounts of iron are transferred to the hand, (B) Ferrotrace mark developed on hand after holding a Colt 45′ pistol, (C) hand grenade mark, (D) Ferrotrace mark after holding a cutter, (E) Ferrotrace mark after carrying a pistol on the hip.*

right hand. Her index finger was clutching the hammer of the gun (Fig. 11).

The man had two bullet holes in his chest, both fired from a close range. The girl had one bullet entry wound in the lower section of her left breast and an exit wound on the right side of her back. In his preliminary assessment, the medical examiner assumed that before committing suicide the woman killed her boyfriend, as he had been shot twice with heavy-caliber bullets, and the gun was found next to her. This was also the message released to the media. After the medical team completed their examinations, Ferrotrace was applied to the hands of the two bodies. The reaction on the woman's index finger was exceptionally strong; its shape matched the upper back of the gun's hammer. There was one puzzling question, however, which had to be answered. The reaction on the finger that touched the gun was very intense, but there was no reaction on the palm of the hand. The absence of a palm reaction raised the suspicion that the woman never really held the gun, and that it had been placed near her hand only after her death. The primary suspect in moving the gun became her boyfriend's brother, who had helped the police enter the apartment. Ferrotrace examination of the boyfriend's right hand indicated that he held the gun both in the regular position (typical of shooting) and in a reverse position (typical of suicide, with the thumb on the trigger, and the index and middle fingers on the safety; Fig. 11). The fact that there were two bullet holes in the man's chest and only one in his girlfriend's did not change the police's conclusion that it was he who shot the girl, and committed suicide. Multiple shots as part of suicide is a known phenomenon, when the first shot is not immediately fatal (25).

I hope that this small selection of actual cases was sufficiently convincing that "forensic science does not start in the lab but in the field."

I wish to thank again the American Academy of Forensic Sciences for granting me this most prestigious award and thanks to all of you for your attention.

FIG. 11—*Resolving a suicide–homicide case by Ferrotrace (25): (A) overview of the crime scene, (B) weapon as found adjacent to girl's right hand, (C) Ferrotrace mark on girl's index finger caused by contact with gun's hammer after death, (D) upper back of gun's hammer, which caused the Ferrotrace stain, (E) Ferrotrace stain on male victim's right hand. (Courtesy: Mobile Laboratory for Serious Crime Scenes, DIFS.)*

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