J Forensic Sci, Apr. 1978, Vol. 23, No. 2

*I. C. Stone,*[1] *Ph.D.; V. J. M. DiMaio,*[1] *M.D.; and C. S. Petty,*[1] *M.D.*

# Gunshot Wounds: Visual and Analytical Procedures

In most instances of death from gunshot wounds, the forensic pathologist is readily able to determine whether or not a particular gunshot wound was inflicted at contact, intermediate, or distant range. In some instances, however, such a determination is virtually impossible. Most difficulty occurs in differentiating a contact wound from a distant wound. A contact wound is apparent when soot[2] is present on the outside of the skin, if there is a muzzle imprint, or if there is tearing of the skin caused by the effects of gas. However, determination of whether a wound is contact or distant can be a problem when (1) the body is decomposed; (2) the deceased has survived days or weeks after the initial wound; (3) the wound is a contact wound and there are multiple layers of clothing that filter out the soot and powder; and (4) the edges of the wound have dried in contact wounds with small caliber weapons.

One method used in an attempt to differentiate contact from distant wounds involves a nitrate stain on sections taken through the wound of entrance. Theoretically, only gunpowder particles are stained a bright blue [*1*]. Interpretation of this stain is subjective and stains may be absent in some contact wounds. This is probably caused by profuse bleeding with the flushing from the wound of any particles of propellant. The presence of only one or two small flecks of blue staining material in the wound is not in itself indicative of a contact wound because a few particles of powder may be carried by the missile into the wound. In addition, since this is really a nonspecific stain, it is possible that other material carried into or present in the wound can give a positive reaction.

The Institute of Forensic Sciences has been using a multifaceted approach that we believe can differentiate contact from distant wounds. After the wound is examined under a dissecting microscope, analysis of the wound is performed by energy dispersive X-ray technics (EDX) for metallic components. These metals may be from the primer (antimony, barium, and lead), vaporized from the cartridge case (copper, zinc, and nickel), or from the bullet (lead, antimony, or copper). The wound track is then swabbed and the swab analyzed by flameless atomic absorption technics (FAAS) for trace metals. This paper presents the initial results of our experience with this multifaceted approach.

## Experimental Procedure

The wound of entrance and associated wound track in subcutaneous tissue are excised and examined under the dissecting microscope for the presence of powder particles and

Received for publication 14 June 1977; revised manuscript received 28 July 1977; accepted for publication 10 Aug. 1977.

[1]Chief, Physical Evidence Section; medical examiner; and director and chief medical examiner, respectively, Southwestern Institute of Forensic Sciences and University of Texas Southwestern Medical School, Dallas, Tex.

[2]The term "soot" is used in this paper to describe succinctly the black, carbonaceous residue caused by gunshot discharge at contact or near-contact range.

powder soot. Those grains which appear suspicious and are not readily identifiable as powder grains can be tested with a hot wire or placed in a spot plate with diphenylamine solution. Work is also underway in evaluating a thin-layer chromatographic procedure developed by Peak of Aerospace Corp. [2] for the identification of powder flakes.

The tissue is then placed on a sheet of Mylar® film over the sample port of a Nuclear Semiconductor/Tracor Northern Model 880 EDX system. This includes the Spectrace 440 automated spectrometer, a molybdenum transmission target tube, and associated electronic components. The kilovolt and milliampere settings are chosen to produce 25% dead time; data accumulation is for 100 s. The elements of interest are lead, copper, zinc, barium, antimony, and nickel.

A plastic-handled, cotton-tipped applicator used for wipings from hands to detect gunshot residue is moistened with 5% hydrochloric acid. The wound track in the tissue is swabbed carefully and the applicator is placed in a test tube. Two millilitres of 5% hydrochloric acid are added and FAAS analysis is performed for lead, antimony, and barium [3]. Wipings for control or blank are useful and can be obtained at autopsy by swabbing tissue about 6 to 8 cm from the wound.

Analysis of wipings from hands for metals characteristic of gunshot residue is performed routinely in all deaths associated with firearms. The hands of the deceased are swabbed with applicators moistened with 5% hydrochloric acid; analysis is done as described by Cone [4].

## Results

The tissues examined have been classified into contact, intermediate, and distant wounds as described by DiMaio et al [5]. Tables 1 to 3 contain the pertinent data associated with each type of wound.

The EDX results are considered positive and significant when the total number of counts in 100 s is at least one order of magnitude, or ten times, greater than the control or normal level for that element; the control sample is tissue from another area of the body. The data obtained by EDX represent the metals present on the surface of the tissue. The wound track swab, analyzed by FAAS, generally represents the metals present in the tissue rather than deposited on the surface.

The data for analysis of wipings from hands are shown in Tables 4 and 5 with the summarized findings of the tissue examination. Atomic absorption with flameless atomization yields results considered positive or significant when the lead level is greater than 2 ppm and antimony and barium levels are at least 0.2 ppm. Listing as inconclusive means at least one of these elements was determined to be below the level of significance.

## Discussion

Each of the contact wounds examined and described in Table 1 consistently exhibits corroborative evidence between visual and analytical data. Powder grains or fragments were observed in 10 of 18, or 56%, of the contact wounds, with powder soot or fouling apparent in every case. In the three instances where clothing was present, both visual and analytical evidence were present for the contact wound.

The cases involving rifles [a 5.5-mm (.22-caliber) single-shot, a 30-06, a 30-30, and an 8.1-mm (.32 Special)] resulted in residues being detected by EDX in only one case, although FAAS analysis did reveal metals characteristic of gunshot discharge in each case, as shown in Table 1.

The ammunition used in Cases 0545 and 0440 (Table 1) was a 5.5-mm (.22-caliber) rimfire. Virtually all 5.5-mm (.22-caliber) ammunition manufactured in the United States contains lead and barium, but not antimony, in the primer; only the ammunition from the Federal Cartridge Corp. contains antimony [6]. Yet the data for Cases 0545 and 0440 in

TABLE 1—*Contact wounds.*[a]

| Case | Visual | EDX | FAAS | Caliber |
|---|---|---|---|---|
| | | Revolver | | |
| 2197-H | powder, soot | lead | lead, barium | .22 |
| 2215-H | soot | lead | lead, antimony, barium | .38 |
| 2387-S | powder, soot | lead, copper | lead, antimony, barium | .32 |
| 2451-H | powder, soot | lead, copper, barium | lead, antimony, barium | .32 |
| 0180-S | soot | lead | lead, antimony, barium | .38 |
| 0230-H | powder, soot | lead | lead, antimony, barium | .38 |
| 0440-S | powder, soot | lead, copper | lead, antimony, barium | .22 |
| 0545-S | powder, soot | lead | lead, antimony, barium | .22 |
| 0659-H | powder, soot | lead | lead, antimony, barium | .38 |
| 0715-S | powder, soot | lead | lead, antimony, barium | .38 |
| | | Pistol | | |
| 2362-S | soot | lead, copper | lead, antimony, barium | .45 |
| 2469-S | soot | copper | lead, antimony, barium | 9 mm |
| 0125-H | soot | lead | lead, antimony, barium | .25 |
| 0488-S | powder, soot | lead | lead, antimony, barium | .380 |
| | | Rifle | | |
| 2213-S | powder, soot | negative | lead, antimony, barium | .22 |
| 0403-S | soot | negative | lead, barium | 30-06 |
| 0679-S | soot | negative | lead, barium | 30-30 |
| 1042-S | soot | lead, barium, copper | antimony, barium | .32 Special |

[a]H = homicide; S = suicide; 1 caliber = 25 mm.

TABLE 2—*Intermediate range wounds.*[a]

| Case | Visual | EDX | FAAS | Caliber |
|---|---|---|---|---|
| | | Revolver | | |
| 0404-H | powder, tattooing | lead, copper | lead, antimony, barium | .22 |
| 0628-H | powder, soot | lead | lead | .38 |
| 0687-H | negative | negative | lead | .22 |
| 0714-H | soot | lead | lead, antimony, barium | .38 |
| | | Pistol | | |
| 0526-H | negative | lead, copper | lead, barium | .25 |

[a]H = homicide; 1 caliber = 25 mm.

TABLE 3—*Distant range wounds.*[a]

| Case | Visual | EDX | FAAS | Caliber |
|---|---|---|---|---|
| | | Revolver | | |
| 0272-H | negative | lead | lead | .38 |
| 0433-H | negative | lead | lead | .38 |
| 0660-H | negative | negative | lead | .38 |
| 0659-H | negative | negative | lead | .38 |
| 0682-H | negative | negative | lead | .38 |
| 0850-H | negative | negative | negative | .38 |
| | | Pistol | | |
| 0464-H | negative | negative | negative | .380 |
| | | Rifle | | |
| 0407 | negative | negative | negative | .22 |
| 1040-H | negative | negative | negative | .32 Special |

[a]H = homicide; 1 caliber = 25 mm.

TABLE 4—*Tissue examinations and metal content in wipings from hands for contact wounds.*[a]

| | Tissue Results | | | |
|---|---|---|---|---|
| Case | Visual | EDX | FAAS | Wiping Results |
| | | Revolver | | |
| 2197-H | + | + | + | left palm |
| 2215-H | + | + | + | left back |
| 2387-S | + | + | + | inconclusive |
| 2451-H | + | + | + | inconclusive |
| 0180-S | + | + | + | inconclusive |
| 0230-H | + | + | + | inconclusive |
| 0440-S | + | + | + | right back |
| 0545-S | + | + | + | right back, left back |
| 0659-H | + | + | + | analysis not done |
| 0715-H | + | + | + | left palm |
| | | Pistol | | |
| 2362-S | + | + | + | inconclusive |
| 2469-S | + | inconclusive | + | left palm |
| 0125-H | + | + | + | inconclusive |
| 0488-S | + | + | + | inconclusive |
| | | Rifle | | |
| 2213-S | + | − | + | inconclusive |
| 0403-S | + | − | + | inconclusive |
| 0679-S | + | − | + | left back |
| 1042-S | + | + | + | left palm |

[a]H = homicide; S = suicide.

TABLE 5—*Tissue examinations and metal content in wipings from hands for intermediate and distant range wounds. All cases are homicides.*

| Case | Tissue Results | | | Wiping Results |
|---|---|---|---|---|
| | Visual | EDX | FAAS | |
| | | Intermediate | | |
| 0404 | + | + | + | inconclusive |
| 0526 | – | + | inconclusive | analysis not done |
| 0628 | + | inconclusive | inconclusive | analysis not done |
| 0678 | – | – | inconclusive | analysis not done |
| 0714 | + | + | + | analysis not done |
| | | Distant | | |
| 0272 | – | inconclusive | inconclusive | inconclusive |
| 0407 | – | – | – | inconclusive |
| 0433 | – | inconclusive | inconclusive | inconclusive |
| 0464 | – | – | – | inconclusive |
| 0659 | – | – | inconclusive | analysis not done |
| 0660 | – | – | inconclusive | inconclusive |
| 0682 | – | – | inconclusive | analysis not done |
| 0850 | – | – | – | inconclusive |

Table 1 show that antimony was detected in the wound even though the ammunition was not of Federal manufacture. The source of the metal is the bullet itself; the 5.5 mm (.22 caliber) is an alloy of lead and antimony. Upon firing, the heat generated by propellant combustion vaporizes some of the bullet metal, producing lead and antimony that can be deposited on the skin and in the wound track at close range. Thus, vaporized bullet metal is detectable in gunshot residues as well as primer components. This is useful in differentiating close range from distant wounds. As indicated in Table 3 and confirmed by our experiments, antimony is not detected in distant entrance wounds even when lead wiped off from the bullet is identified.

In a separate study involving tissue removed during surgery [7], both EDX and FAAS technics showed that jacketed and lead bullets carried metals into tissue at ranges of 2 to 3 m. These metals are probably picked up by the missile passing through the barrel and are accumulated from previously fired rounds. Layers of clothing diminish these metallic levels, as does the flushing action of blood and body fluids from a wound.

Table 2, describing intermediate wounds, is particularly interesting in that one of the individuals autopsied (Case 0526) was in an advanced state of decomposition. There was no gross or microscopic evidence of gunshot residue, yet EDX and FAAS clearly reflected metals of significance.

The results shown in Table 3 for distant wounds reflect what one would expect, that is, that some evidence of wipings from bullets might be present but no metals characteristic of primer residue or cartridge case vaporization would be detected. We have observed the same conditions when the apparent bullet hole is through clothing. Visual examination, soft X-ray, and analysis for metals occasionally yield evidence for wipings from bullets but no other metals or residues of significance.

The importance of having clothing available for examination in all gunshot wound cases is illustrated clearly by Case 0687 in Table 2. This involved a man who was shot in the chest by his wife at a range of about 0.3 m (1 ft). Visual and analytical examinations of the intervening clothing showed evidence of gunshot residues, but the tissue examination

results indicated a distant wound. Contact wounds through clothing usually do not present the problems described for intermediate wounds as the soot, powder, and trace metals are deposited in the wound.

Hair may filter out powder and soot and reduce or eliminate powder tattooing just like clothing. The primer residues and vaporized bullet metals are still detectable, however. A grocery store clerk was murdered during a robbery in April 1977, and tissue and hair were obtained. No powder or soot was observed on the hair or tissue, and the EDX and FAAS analyses of the tissue yielded no significant metallic deposits. The metallic residues on the hair, however, indicated that a weapon had been discharged close enough to leave significant lead, antimony, and barium deposits.

In a previous paper [*3*] the authors described the innovation of test firing weapons in suicide and homicide cases and analyzing the resultant wipings from hands for lead, antimony, and barium. This provides a control to determine if the weapon in question leaks metallic residues of significance. This is still done in selected cases and provides invaluable information in deciding whether or not significant metallic residues are present.

Another interesting finding has been the identification of metals on surfaces of the hands that are consistent with the hands being in a defensive gesture. For instance, a police officer was shot by an assailant and the eyewitnesses reported he tried to push the gun away with his left hand. The wiping from the left palm contained the only metallic residue detectable by FAAS. In several other cases where store owners have been shot by armed robbers, metals characteristic of gunshot residues were found on the palmar surfaces of the hands of the deceased.

In another case, a person died 32 days after a self-inflicted gunshot wound. Visual examination of the healing wound revealed traces of powder soot. The EDX analysis yielded data for lead that were about ten times background level. The microscopic examination of tissue stained for nitrates showed positive evidence of powder.

The examination and analysis scheme described can be done without excision of tissue although EDX analysis is useful for corroboration of close range wounds. Visual examination at autopsy plus the swabbing of the wound may be sufficient and eliminate the need for the relatively expensive EDX apparatus.

The examination and analysis should be performed shortly after excision and before fixing. An extension to this work will be the study of the effect of fixing tissue and subsequent gunshot residue detection.

## Summary

Visual examination of clothing and tissue from gunshot wounds provides information pertaining to the range of discharge of a firearm. Identification of powder grains or soot is evidence of close range discharge by a handgun. Analyses of tissue by EDX and FAAS technics are shown to supply corroborating data to visual examination in estimation of range. These methods are of particular value in differentiating contact and distant wounds when decomposed bodies are examined and when multiple layers of clothing are present.

## References

[*1*] Rolfe, H. C., Carl, D., and Simmons, D., "A Histological Technique for Forensic Ballistics," *Journal of Forensic Medicine*, Vol. 18, No. 2, 1971, pp. 47–52.

[*2*] Peak, S. A., "A Thin-Layer Chromatographic Procedure for Confirming the Presence and Identity of Smokeless Powder Flakes," prepublication procedure, Aerospace Corp., El Segundo, Calif., 1977.

[*3*] Stone, I. C. and Petty, C. S., "Examination of Gunshot Residues," *Journal of Forensic Sciences*, Vol. 19, No. 4, Oct. 1974, pp. 784–788.

[4] Cone, R. D., "Analysis of Gunshot Residue by Flameless Atomic Absorption Spectrophotometry," presented at the 26th Annual Meeting of the American Academy of Forensic Sciences, Dallas, Tex., Feb. 1974.
[5] DiMaio, V. J. M., Petty, C. S., and Stone, I. C., "An Experimental Study of Powder Tattooing of the Skin," *Journal of Forensic Sciences,* Vol. 21, No. 2, April 1976, pp. 367-372.
[6] Meyers, R. E. and Kopec, R. F., "Identification of .22 Caliber Rimfire Ammunition Suitable for Gunshot Residue Determination," *Identification News,* Sept. 1976, pp. 10-12.
[7] Stone, I. C. and DiMaio, V. J. M., "Metallic Residues in Gunshot Wounds," *Journal of the Association of Firearms and Toolmark Examiners,* May 1977.

Address requests for reprints or additional information to
I. C. Stone, Ph.D.
Southwestern Institute of Forensic Sciences
P.O. Box 35728
Dallas, Tex. 75235