TECHNICAL NOTE

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Study of Inorganic Residues Around Entrance and Exit Projectile Orifices

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ABSTRACT: Lead, antimony, and barium determinations have been made at entrance and exit orifices produced by firearms. Gunshots were made at seven different distances: 20, 40, 80, 200, 500, 1000, and 2500 cm using two kinds of ammunition. Our results demonstrate the usefulness of these elements to make a differential diagnosis between entrance and exit orifices produced by firearms; they are also useful to determine the distance between the firearm and the victim.

KEYWORDS: criminalistics, ballistics, gunshot residues, lead, antimony, barium, atomic absorption spectrophotometry with graphite furnace

Wounds from firearms can present delicate problems to forensic science specialists [*1,2*]. That is why it is sometimes necessary to use many criminalistic techniques to reconstruct the events. Suspect firearms, trajectory, distance, and projectiles are some of the problems to resolve. In these situations of firearm wounds, metallic particles from cartridge, projectile, and so forth can offer important information [*3,4*].

Many methods have been proposed for the investigation of these particles: atomic absorption spectrophotometry (AAS) [*3-7*], neutron activation, scanning electron microscopy with dispersive energy analysis [*8*], colorimetric tests (sodium rhodozianate), Weisz ring [*9*], and so forth.

The present work is based on a contradictory legal survey that we had done at our Department: a skirt was sent to our laboratory to establish the distance between the firearm and the victim in a case of death by gunshot.

We made an investigation of gunpowder residues following the Griess-Lung modified

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technique. The results were negative and we analyzed the lead, antimony, and barium concentrations by AAS at the entrance and exit projectile orifices.

Our results about the identification and distinction between the entrance and exit projectile orifices were not the same as the ones obtained by the pathologists at the autopsy. This posed a very tough question: what proof had more value?

In the beginning, we gave preeminence to the results of the autopsy because it is well known that the diagnosis of wounds from firearms (differential diagnosis between entrance and exit projectile orifices) is usually easy to do at the autopsy.

Nevertheless, we started an investigation about this case, and we show in this work the first results we have found.

We have to take into account that in the references there are works about the investigation of lead, barium, and antimony for establishing the distance from the firearm to the victim, but there are no references for the differential diagnosis between entrance and exit orifices. As we have expressed before, we think that it is due to the normally easy resolution of this problem at the autopsy.

Material and Methods

We have employed a Star 28 PK 9-mm pistol with two kinds of ammunition: armored and semi-armored.

With each kind of munition we have taken five shots at seven different distances: 20, 40, 80, 200, 500, 1000, and 2500 cm. These shots were made to a figure made by ourselves that tried to imitate reality: it was compounded by five different strata that were penetrated by the projectile in this order: skirt/skin/pasteboard/skin/skirt. (Skin used was domestic pigskin.) So, we had four orifices to study after every gunshot:

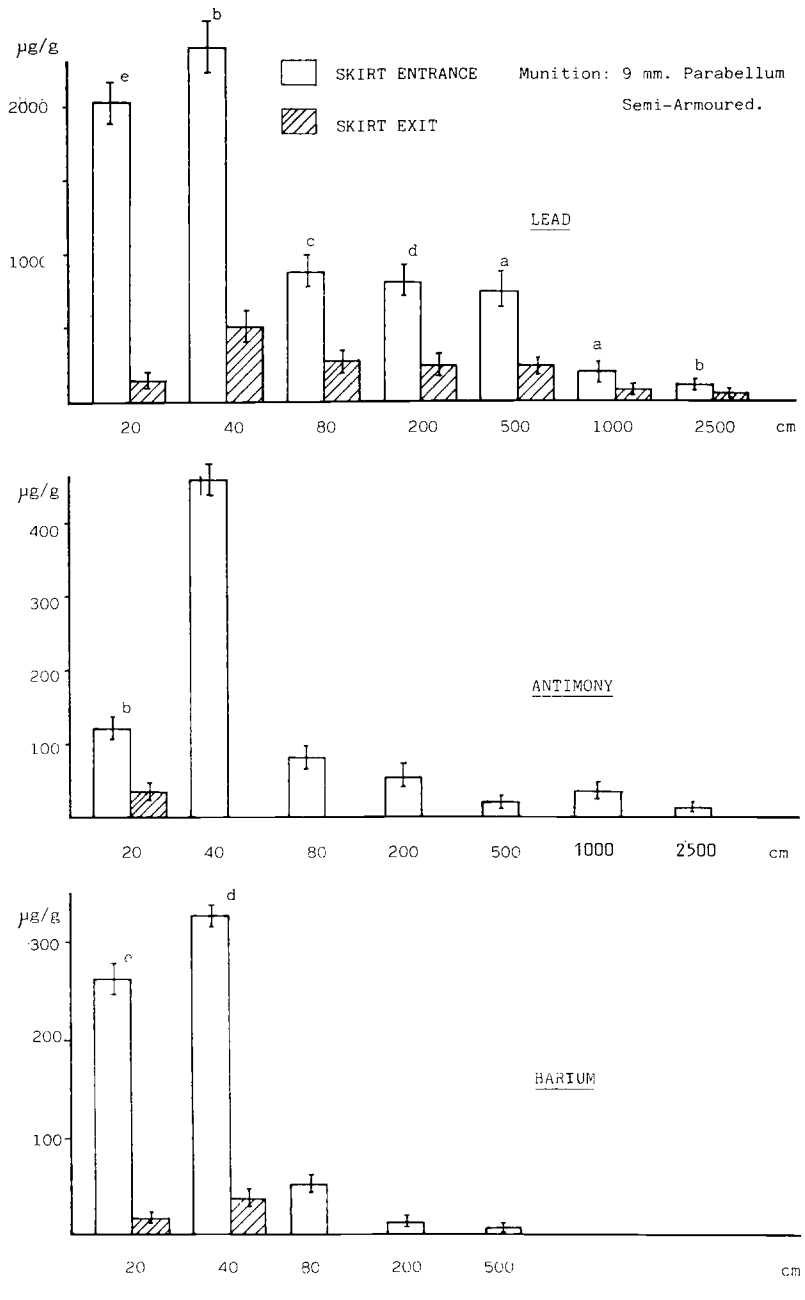
(1) entrance skirt orifice,
(2) entrance skin orifice,
(3) exit skin orifice, and
(4) exit skirt orifice.

Every sample (that includes a small piece of 2 cm of diameter, concentric around the orifice) of skirt and skin and its controls (piece of skirt or skin of the same size, located at 12 cm from the orifice) were exactly weighed and stored at 4°C until used.

Tubes for determinations were washed with 5% nitric acid (HNO_3) for 18 h.

TABLE 1—*The AAS conditions used for determinations.*

Element	Step	Temperature, °C	Ramp Time, s	Hold Time, s	Detection Limit, mg/L
Lead	1	120	30	30	0.000 05
	2	520	15	12	
	3	2300	1	5	
Antimony	1	110	20	20	0.000 2
	2	1000	20	20	
	3	2300	0	5	
	4	2600	1	3	
Barium	1	110	15	20	0.000 04
	2	1000	20	20	
	3	2300	0	5	
	4	2600	1	3	



a= p<0.001; b= p<0.01; c= p<0.02; d= p<0.05; e= p<0.1

FIG. 1—*Statistical difference between skirt entrance and exit for 9-mm parabellum semi-armored munition.*

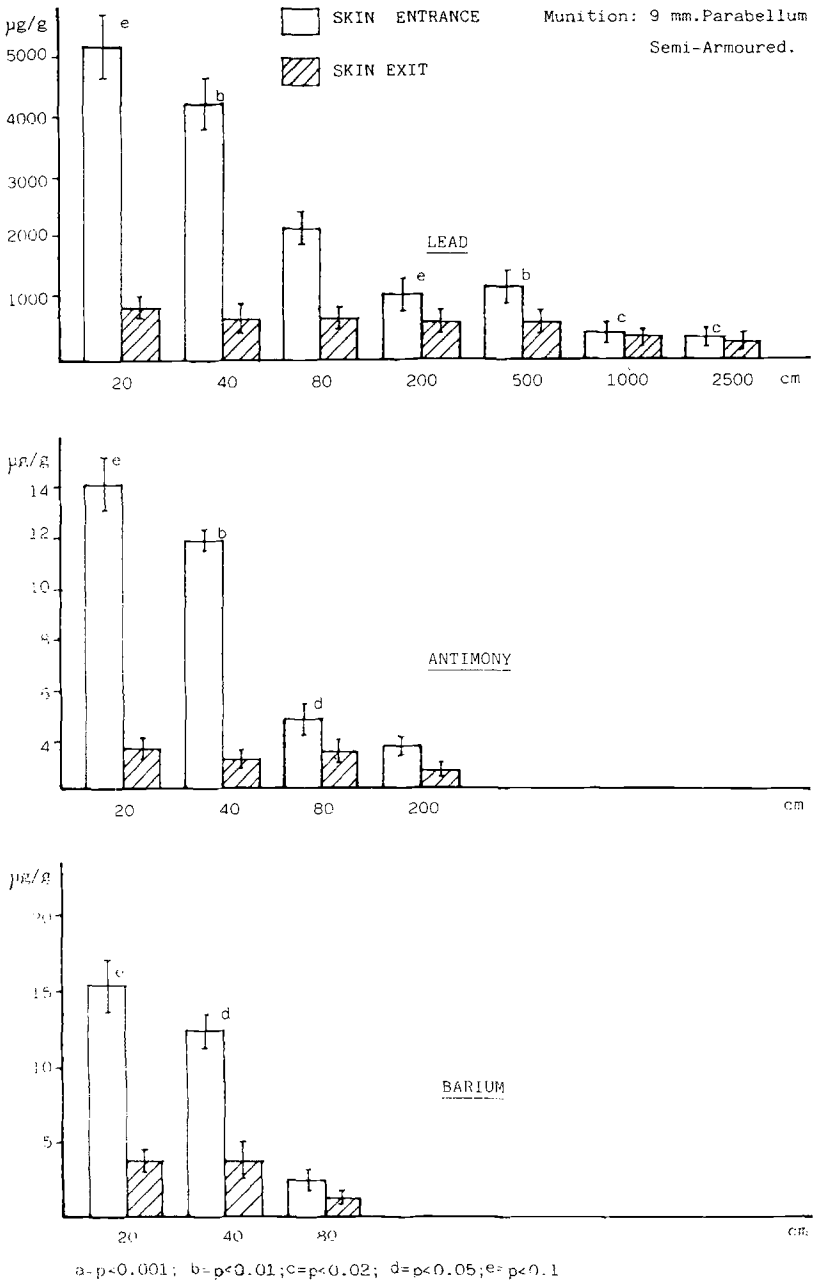


FIG. 2—*Statistical difference between skin entrance and exit for 9-mm parabellum semi-armored munition.*

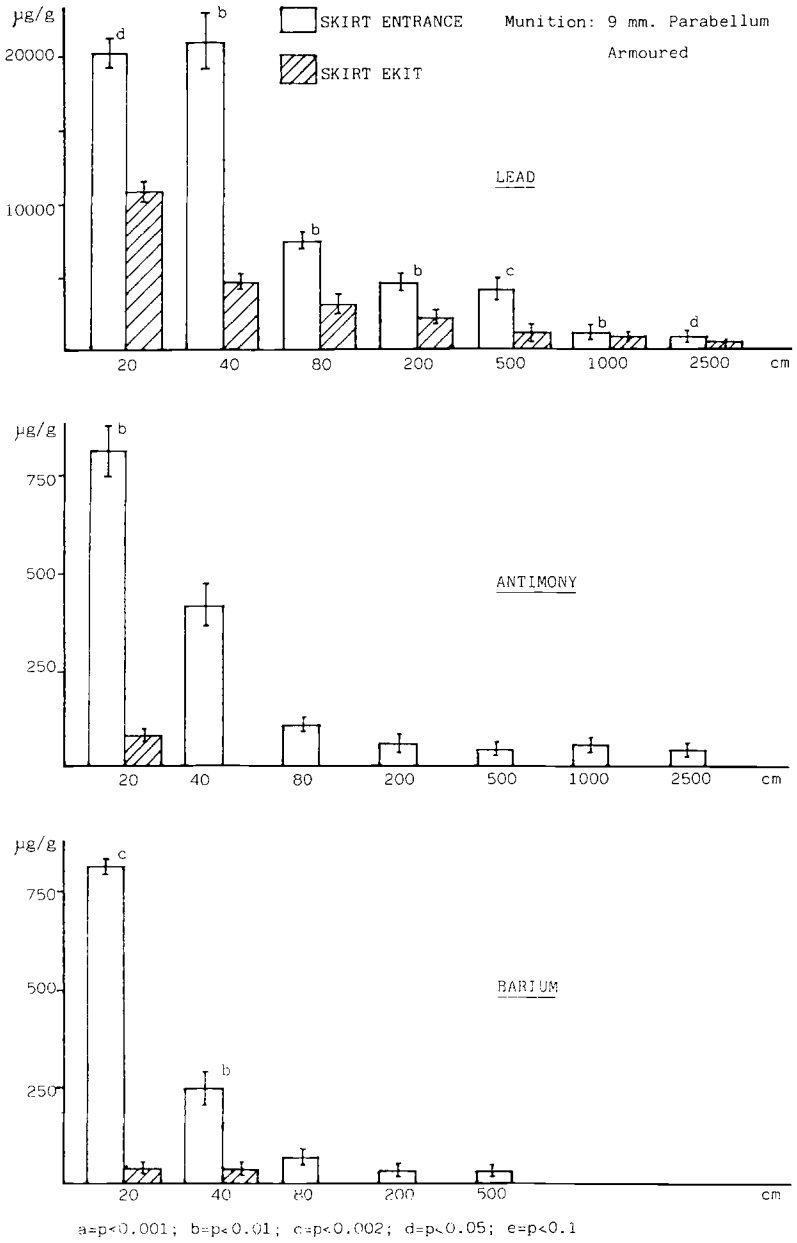
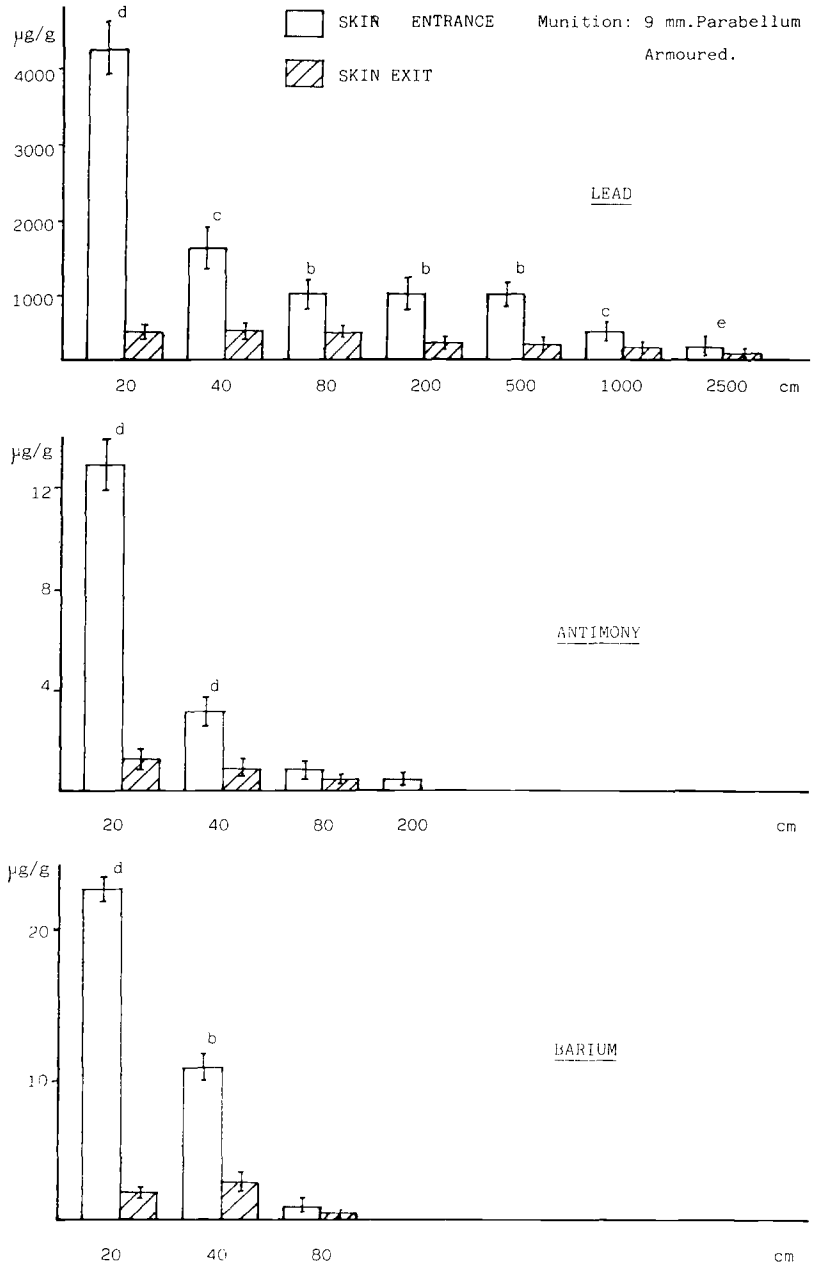


FIG. 3—*Statistical difference between skirt entrance and exit for 9-mm parabellum armored munition.*



a: p<0.001; b= p<0.01; c= p<0.02; d= p<0.05; e= p<0.1

FIG. 4—*Statistical difference between skin entrance and exit for 9-mm parabellum armored munition.*

FIG. 5—*Correlation between lead concentrations (μg/g) and distance.*

Skirt and skin samples were treated with 0.4 and 1 mL of 20% HNO_3, respectively, and boiled at 80°C for 30 min. Aliquots of these solutions were diluted ten times with 20% HNO_3 to be processed by AAS (see Table 1 for determinations).

The instrumentation consisted of an atomic absorption spectrophotometer (Perkin Elmer Model 560), graphite furnace (Perkin Elmer Model HGA-400), and hollow cathode lamps (Perkin Elmer for lead, barium, and antimony).

Variation coefficients (VC) calculated with ten determinations of the same sample were 3.26% for lead, 6.78% for barium, and 4.31% for antimony.

Results and Discussion

Our results have demonstrated statistical differences between entrance and exit orifices, as shown in Figs. 1 to 4. These confirm conclusions of many authors [*3,5,6*] in prior studies of this topic.

In previous works at our Department, we have studied the behavior of some ions by AAS to determine firing distances; in these studies, iron, cadmium, copper, and zinc had a very irregular behavior not viable for a solution of this kind of problem.

Nevertheless, according to many authors, the ions lead, barium, and antimony give very good results. This is the reason why we have chosen lead, barium, and antimony for this study [*2,4,10*].

We do consider that lead, barium, and antimony determination is very useful to analyze firearm shots. We also consider that lead is the most useful because its high concentrations let investigators make differential diagnoses between entrance and exit orifices and, besides, determine the distance between the firearm and the victim.

Antimony and barium results have to be validated after a detailed study. Their presence only at entrance orifices—and not at exit ones—in distances larger than 80 cm at skin and 40

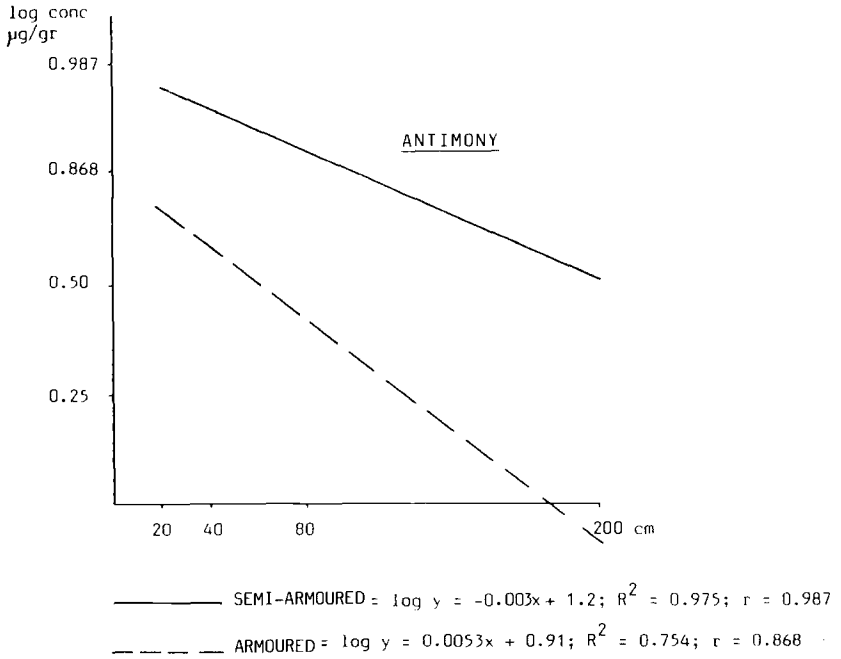


FIG. 6—*Correlation between antimony concentrations (µg/g) and distance.*

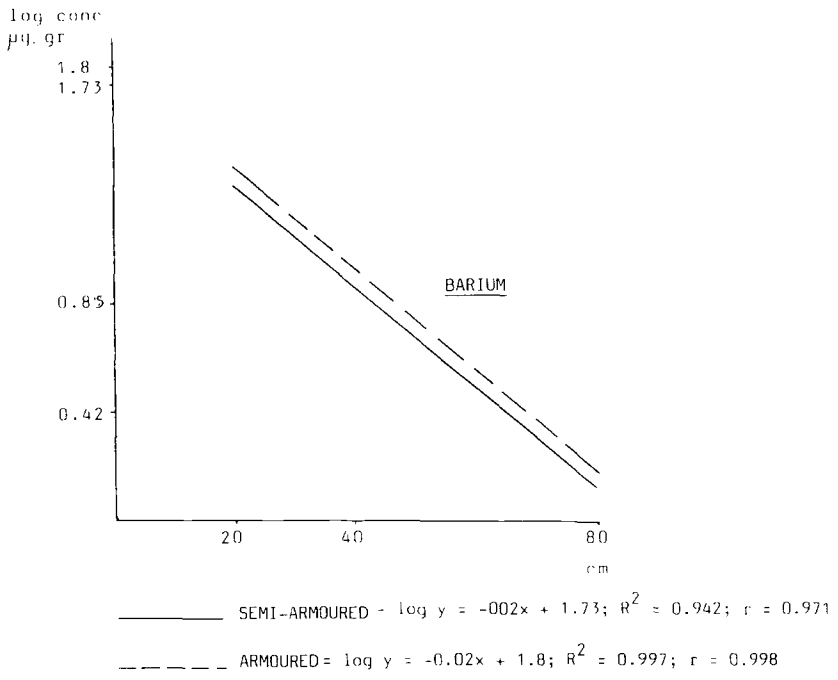


FIG. 7—*Correlation between barium concentrations (µg/g) and distance.*

cm at skirt, confers upon them a great value to determine the entrance orifice in cases of firearm shots [*3-6,10*].

We have found good correlation among the different elements and the different distances at entrance skirt and skin orifices, according to an exponential function as shown in Figs. 5, 6, and 7, having excellent correlation coefficients.

Nevertheless, no correlation among the different elements themselves indicates to us that they have different origins (projectile, gunpowder, percussion-cap, and so forth).

Conclusion

In summary, we think this technique may be very useful to differentiate entrance from exit orifices, and also to establish the distance between the firearm and the victim.

If we could make experimental firings with the gun and the ammunition implicated in the affair that initiated this work, we could obtain results that would perhaps be more definitive.

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