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Short Communication

# Distinction between entrance and exit wounds by energy dispersive X-ray fluorescence spectrometry

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ABSTRACT

We investigated gunshot wounds in two autopsy cases using energy dispersive X-ray spectrometry (EDX). Lead and copper were detected in the entrance wound of one case and lead, antimony, and copper were detected in that of the other case. In the exit wounds of both cases, lead, antimony, and copper were below detection limits. These findings indicate that the detection of metallic elements, such as lead, antimony, and copper, which are found in bullets, may be useful for differentiating entrance from exit wounds using EDX.



## 1. Introduction

The examination of gunshot wounds is important in forensic practice for reconstruction of the shooting incident [1–3]. The distinction between entrance and exit wounds is a one of the main means of estimating the range of fire or direction of the shooting [1–3]. The distinction between entrance and exit wounds is determined by macroscopic findings, based on morphological characteristics in typical cases. However, it is not always easy, and an atypical wound may be observed in some cases.

Because lead (Pb) concentration around entrance wounds is higher than that around exit wounds, the quantification of inorganic Pb concentration is used as a supporting measure for the distinction between the two [4]. Ohtsuji et al. use atomic absorption spectrometry (AAS), a sensitive instrument, but sample preparation methods are destructive and extensive. A high degree of metal deposition is typically observed in entrance wounds [5]. It has been reported that energy dispersive X-ray spectrometry (EDX) is useful for the detection of metallic elements in paraffin-embedded tissue [6]. EDX is a simple and non-destructive way to detect various elements in various types of samples [7–10].

In the present study, we attempted to use EDX to distinguish between entrance and exit wounds by direct measurement of skin samples without special preparation.

## 2. Materials and methods

### 2.1. Case history

Case 1. A man in his seventies was found dead in his room. There was a handgun beside him. At autopsy, two gunshot wounds were found, one on the anterior chest wall and the other on the back. There was a round-shaped 1.7 × 0.9 cm skin defect with a dark ring of soot surrounded by a rim of abrasion on the anterior chest wall (Fig. 1a). Rupture of the heart was observed in an intracorporeal channel in the thoracic cavity; and there was a slight irregular perforation of 0.5 cm in diameter, with a surrounded purplish-red discoloration on the back (Fig. 2b). The cause of death was heart rupture due to gunshot injury. From the macroscopic morphological findings, we concluded that the entrance wound was in the anterior chest wall, and the other was an exit wound, respectively, and the entrance would was considered to be a contact or near-contact wound.

Case 2. A man in his fifties was found dead in his room. There was a handgun near his hand. At autopsy, two gunshot wounds were found, one on the anterior chest wall, and the other on the back. There was a round-shaped 2.0 × 1.5 cm skin defect with a dark ring of soot and deposition of metallic substances, surrounded

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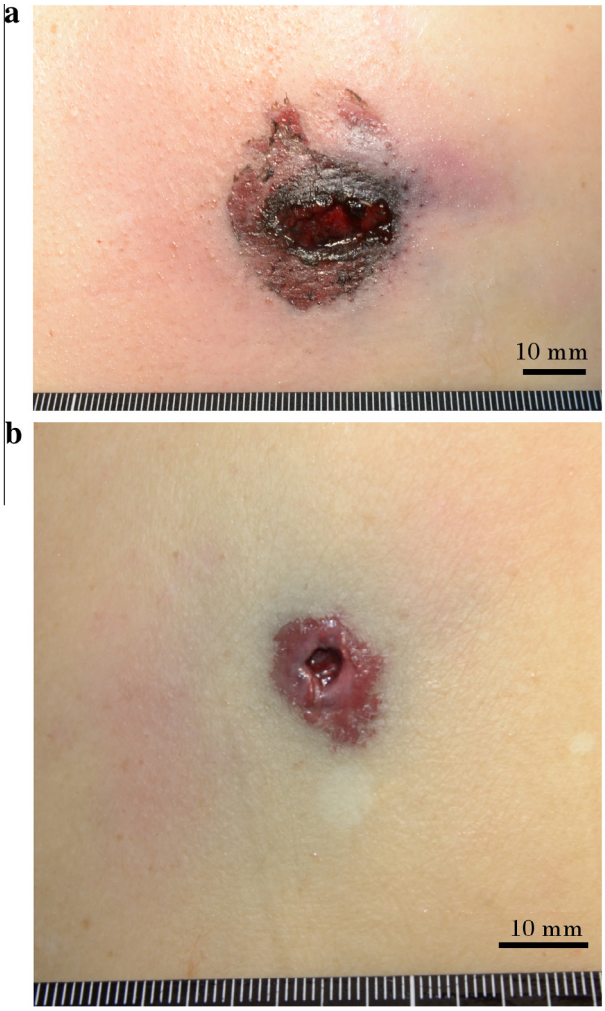


**Fig. 1.** Gunshot wounds in Case 1 (a, wound in anterior chest wall; b, wound in back region). Bar: 10 mm. There is a round-shaped skin defect with a dark ring of soot surrounded by a rim of abrasion in the anterior chest wall; and there is a slight irregular perforation with a surrounding purplish-red discoloration on the back. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

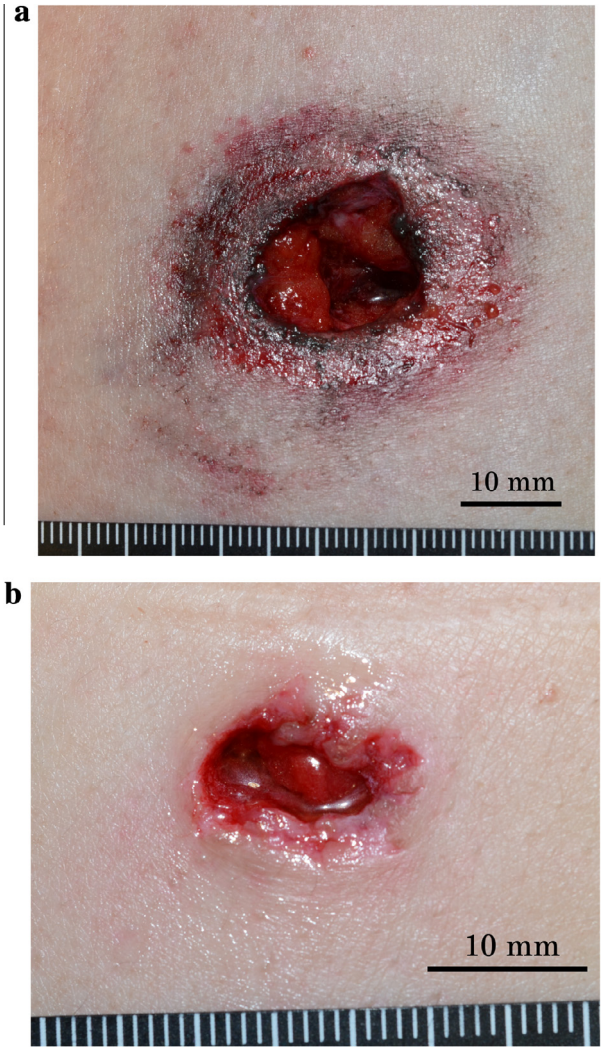


**Fig. 2.** Gunshot wounds in Case 2 (a, wound in anterior chest wall; b, wound in back region). Bar: 10 mm. There is a round-shaped skin defect with a dark ring of soot and deposition of metallic substances, surrounded by a rim of abrasion, on the left anterior chest wall; and there is an irregular perforation, without abrasion, on the back.

by a rim of abrasion, on the left anterior chest wall (Fig. 2a). Rupture of the lung was observed in the thoracic cavity; and there was an irregular perforation 1.4 × 0.7 cm in size, without abrasion, on the back (Fig. 2b). The cause of death was blood aspiration due to gunshot wound of the chest and lung. From the macroscopic morphological findings, we concluded that the entrance wound was in the anterior chest wall, and the other was an exit wound, respectively, and the entrance wound was considered to be a contact or near-contact wound.

The samples of skin around the wounds on the anterior chest wall and back region were collected and fixed in formalin.

### 2.2. Procedure for EDX analysis

We applied elemental analysis by EDX to the formalin-fixed skin samples. A Rayny EDX-720 system (Shimadzu, Kyoto, Japan) was used. The operating conditions for EDX instruments followed those described in a previous report [11–13]. In brief, target: rhodium anode, operating voltage: 50 kV, X-ray path: air, detector: silicon (lithium), and measurement time: 100 s. The measurement area was 10 mm in diameter. For the examination by EDX, formalin-fixed tissues were dried at room temperature and directly placed on a sample cup (Double open-end X-RA, Shimadzu, Kyoto, Japan) with polyester thin film (Mylar film, Shimadzu, Kyoto, Japan). The sample cup was placed on the sample stage of the equipment without any further preparation. Identification of the elements was based on their unique energy characteristics on X-ray, according to the manufacturer's instruction.

## 3. Results and discussion

We show the EDX spectra of skin samples of Cases 1 and 2 in Figs. 3 and 4, respectively. In Case 1, Pb and copper (Cu) were detected in the anterior chest wound, but both Pb and Cu were below the detection limit in the wound skin from the back region (Fig. 3). In Case 2, Pb, antimony (Sb), tin (Sn), and Cu were detected in the anterior chest wound, but they were below the detection limit in the back region (Fig. 4). Bullets usually contain Pb, Sb, and barium in the primer, and Cu and zinc in the metal jacket [1–3,14]. We detected metallic elements such as Pb, Sb, and Cu from direct examination of formalin-fixed skin samples, not using paraffin-embedded samples, as reported previously [6]. As Pb concentrations around entrance wounds are reported to be higher