Journal of Forensic Radiology and Imaging 3 (2015) 147–152

Contents lists available at ScienceDirect

Journal of Forensic Radiology and Imaging

journal homepage: www.elsevier.com/locate/jofri

Identification of bullet entrance in different type of intermediate firearm wounds through micro-computed tomography analysis

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ARTICLE INFO

Article history:
Received 21 April 2015
Received in revised form
15 June 2015
Accepted 19 July 2015
Available online 20 July 2015

Keywords:
Forensic radiology
Forensic ballistics
Micro-CT
Gunshot wounds
GSR
Entry wound
Exit wound

ABSTRACT

Objectives: The aim of the study was to compare, by means of micro-computed tomography (micro-CT), intermediate gunshot wounds produced on human skin, in order to perform a differential diagnosis between entry (EntW) and exit (ExtW) wounds.
Materials and methods: Thirty firing trials were carried out at a distance of 15 cm. Six shooting experiments were performed on human calves covered with a single layer of textile; the other 24 firing trials were carried out on bare skin sections.

The bare skin specimens ($n=6$) and those covered by textile specimens ($n=6$) were immediately formalin-fixed. The remaining gunshot wounds were submerged in water for 1 day ($n=6$), or enclosed in a cowshed for 15 days ($n=6$) or placed inside a wood-burning stove for 4 min ($n=6$). The entrance and exit wounds were analyzed macroscopically and microscopically, as well as radiologically using a micro-CT, and the results were compared by blinded investigators.
Results: At visual inspection, the differential diagnosis between entrance and exit holes was possible only in fresh and submerged gunshot wounds, while the skin of the other types of lesions did not show any of the classical morphological features of entrance wounds.

Micro-CT analysis detected radiopaque particles in each experimental sample only on the EntW, while on the ExtW no gunshot residue (GSR) deposits were evident.
Conclusion: Micro-CT analysis detected GSR in EntW, allowing the performance of a differential diagnosis from the ExtW. This objective and rapid tool may furnish precious information for reconstructing the shooting incident in firearm fatalities.

1. Introduction

The use of radiological techniques for the study of gunshot wounds is well established in forensic medicine. The virtual autopsy ("Virtopsy") may aid in the detection and precise spatial localization of foreign bodies such as metallic fragments or projectiles and guide the forensic pathologist during bullet retrieval [1–3]. In addition, 3-dimensional postmortem computed tomography can be used to document the bullet path by depicting typical gunshot wound fracture patterns, discriminating osseous entry (EntW) and exit wounds (ExtW) and evaluating any associated tissue damage prior to autopsy [4–6].

Recently, micro-computed tomography (micro-CT), a radiological technique which provides greater spatial resolution with respect to clinical computed tomography [7], has also been utilized for the examination of gunshot wounds in human skin, in order to perform tridimensional reconstructions of the spatial distribution of gunshot residues (GSR) particles [8–11].

The aim of the present study was to analyze, by means of micro-CT, intermediate gunshot wounds produced on human skin under different experimental conditions (fresh, covered by textile, submerged, decomposed, charred), in order to evaluate and compare the morphology and the distribution of GSR, with the final purpose of performing a differential diagnosis between EntW and ExtW.

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http://dx.doi.org/10.1016/j.jofri.2015.07.004
2212-4780/

2. Materials and methods

2.1. Firing trials and samples collection

After approval of the Ethical Committee of the University-Hospital of Padova (Protocol n. 2013P), 30 sections of approximately 6 cm in length obtained from human legs surgically amputated for medical reasons (circulatory disorders, road or workplace trauma), were used as targets. Inclusion criteria were: male gender and aged between 20 and 50 years. Exclusion criteria were: neoplastic and/or inflammatory and/or infective diseases of the skin, scars, and traumatic wounds. Each calf was washed to remove dirt, dried blood and any other contaminants from the skin surface. Three calf sections were obtained from each leg. To avoid wound contamination by bone fragments [11], soft tissues were carefully separated from the bones with a scalpel, and the resulting cavity was filled with pieces of muscle and their surrounding fat excised from the thigh.

All the shooting experiments were conducted during the month of July in the countryside around Padova (Veneto region, Italy), using a.32 ACP pistol (Beretta Mod. 81) loaded with full-jacketed bullets (7.65×17 mm^2, Browning SR), and ammunitions originating from the same production lot.

At the muzzle-to-target distance of 15 cm, 24 firing trials were made into bare calf sections (Fig. 1A), and 6 test shootings were carried out on samples enveloped with a single layer of textile material made of cotton (Fig. 1B).

After the shooting tests:

1. 6 bare calf sections (group 1) and 6 covered by textile fabric calf sections (group 2) were immediately formalin fixed (4%, pH 7.4) to avoid autolysis;
2. 6 bare calf sections were placed in water inside a plastic box for 1 day, at an average temperature of 28 °C (group 3);
3. 6 bare calf sections were enclosed inside a wooden box, covered by a mosquito net to avoid maggot infestation, and placed in a cowshed for 15 days, at an average temperature of 24 °C (group 4);
4. 6 bare calf sections were placed inside a wood-burning stove for 4 min, at a temperature of 600 °C (group 5).

The gunshot wounds (EntW and ExtW) were photographed using a Nikon D-90 digital camera equipped with AF-S Nikkor 18–105 mm (Nikon Corporation, Shinjuku, Japan).

2.2. Visual inspection

Visual inspection was performed by a forensic pathologist with a long experience on the ballistics field, blindly to the experimental conditions.

2.3. Micro-CT analysis

Two specimens, comprising the epidermis, dermis and subcutaneous fat around the EntW and ExtW were obtained from each calf section, cut into parallelepipeds (height 1 cm, side 1 cm) with the gunshot wound in the middle, and then located in a cylindrical polyethylene container (1.1-cm-diameter).

All specimens were analyzed by an ex-vivo high resolution MicroCT 1172 (Skyscan, Aartselaar, Belgium). The acquisition and reconstruction settings, in addition to the parameters of the 3-D reconstructions, were performed according to the protocol described by the authors in a previous study and applying the same software [8].

Micro-CT settings were as follows: 100 kV of voltage; 100 μA of current; an aluminum filter of 1 mm of thickness to reduce the beam-hardening artifact; 13 μm of isotropic voxel size; 1280×1024 pixel of field of view. The selected volume of interest (VOI side of 1 cm and height of 3.8 mm) was focused in the center of the specimen to include the entire entry wound. Since GSR

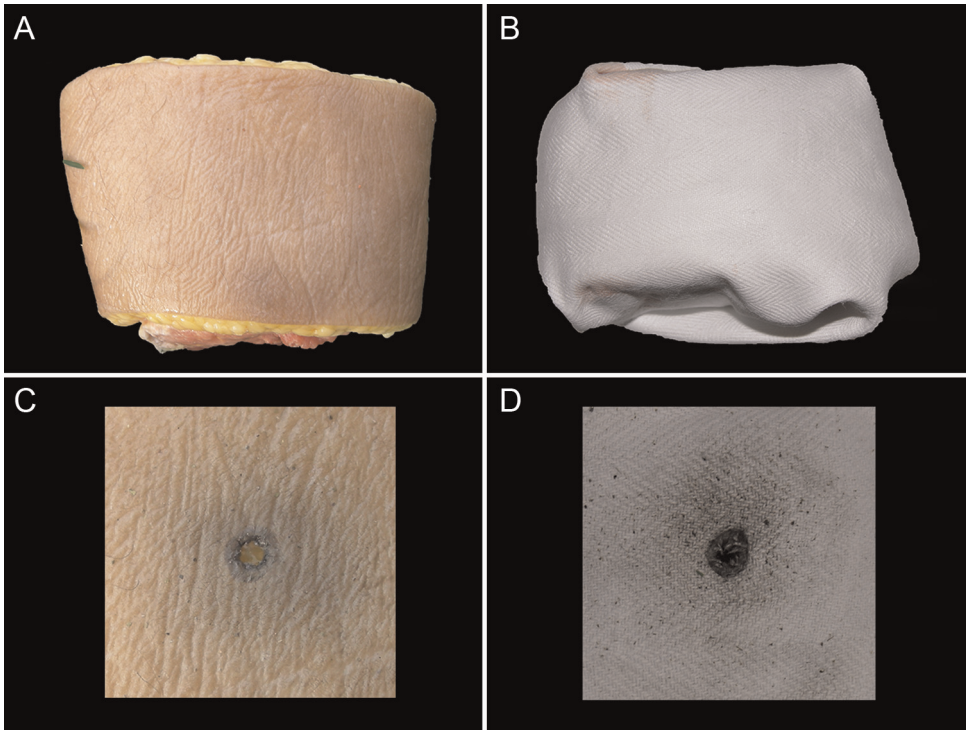

Fig. 1. Bare skin (A) and covered by textile fabric, (B) calf sections before the shooting trial. Powder particles and blackening around the entrance wound produced on bare calf section (C) and the entrance hole of the cloth (D).