Post-mortem computed tomography (PMCT) techniques in forensic investigations of fatal gunshot wounds

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Learning objectives

The aims of this education exhibit are:

- to understand the role of PMCT in forensic investigations of gunshot fatalities;
- to discuss the contribution of PMCT in the definition of the entrance and exit wound, and of the bullet track;
- to suggest indications and protocols.
Background

The modern CT techniques are widely introduced in field of forensics during litigation and at trial.

In forensic investigations on gunshot wounds, radiology techniques are recognized as invaluable methods and universally used to locate the bullet, identify the type of weapon and ammunition, define entrance and exit wound, document the track of the bullet, and to assist in the retrieval of the bullet [1-6]. These data are obviously crucial in every forensic investigation of gunshot wounds.

In the last 30 years, the connection between radiology and forensic medicine has been revitalised by the remarkable progress of diagnostic imaging and the introduction of computed tomography (CT) in forensic investigations on corpses. This phenomenon was prompted by the development of spiral CT due to its capability of 3D acquisitions and postprocessing. Actually, PMCT is recognized as a standardised modality for evaluating gunshot wounds, at least in the cranial district [2-4, 6].

Due to their 2D and 3D reconstruction capabilities these techniques are considered useful particularly in forensic investigation of death by gunshot injuries for their ability to define the bullet's entry and exit wound, the path of the projectile through the body, and the location of the bullet in penetrating wounds.

Definitions in Forensic Pathology

Entrance wound versus exit wound

Differentiation of entrance and exit wounds is based classically on some morphological and biophysical changes in clothing and skin, hair and bone [7-8]. In particular, depending on the distance of shooting, the following findings can indicate the entrance wound:

- in contact wound without interposition of clothing the shape is circular reproducing the bore of the weapon, even with a muzzle impression, with minimal soiling and burning of the skin;

- in cases of close discharge, if the body surface is uncovered, the skin at the entrance wound may appear burned or there may be a wide flare or narrow rim of hyperhaemia; there might be a "soot staining" of the skin from carbon deposition; the wound is circular if the weapon is held at right angles to the skin and elliptical if slanted

- in cases of mid- to distant-range shotgun discharge (15 cm to 2 m) the appearance of the entrance wound may vary considerably. Over 20-40 cm soot soiling may vanish. The edge of the wound become crenated and scalloped.
In cases where a bone structure is present, i.e. the skull, sternum, a beveling of this can be found with a cratering of the inner bone surface.

On the other hand, the exit wound is characterized by a random appearance, depending on the anatomical part and the presence of any bone or tissue fragments blown out in the discharge [7-8].

For example, in cases where a bone structure is present, i.e. the skull, sternum, a beveling of this can be found with a cratering of the outer bone surface and bone fragments are blown out, eventually causing multiple lacerated wounds.

Another fundamental aspect in head gunshot wounds is the study of the fracture lines radiating from the bullet entrance and exit holes. In 1903, Puppe introduced the principle [8] whereby when several fracture lines are present on the skull, it is possible to reconstruct the sequence of injuries by studying their intersection or, in the case of gunshot wounds, convergence towards the bullet hole.

Wound track and direction of the gunshot wound

The wound track and the direction of the gunshot wound can be classically [7-8] determined at autopsy if one assumes that it will follow a straight course between the entrance and the exit wounds or between the entrance wound and the projectile in penetrating wounds. Nevertheless, in some rare cases, the bullet may deviate by the linear course within the body and stop at sites totally unrelated to the original trajectory as a result of the impact with bone or interposed tissues.

Nevertheless, in all cases, crucial information for the definition of the projectile track and of the direction of the trajectory can be derived by the analysis of tissue damage along the track, the characteristics of bone defects, the location and distribution of bone/projectile fragments.
Findings and procedure details

The forensic radiology literature proposes some clues for differentiation of the entrance and exit wound and description of the bullet path [1-6]. In particular, the forensic analysis of gunshot wound fatalities is made through the study of the tissue lesions, including bone fractures, the description of the distribution of bone and bullet fragments.

Here, the contribution of PMCT in forensic investigations on gunshotwounds is discussed.

Entrance vs exit wound

As previously described, the differentiation of entrance and exit wounds is based classically on some morphological and biophysical changes in clothing and skin, hair and bone [7-8]. PMCT is limited in the description of superficial and skin lesions [1-6]. Nevertheless, due to 2D and 3D reconstruction possibilities PMCT techniques are considered of some value in differentiating entrance and exit wound, when bone structures are involved (i.e. in the head gunshotwounds) [1-6].

In fact, in these cases, PMCT is able to describe and to differentiate the entry from the exit wound (when present), through (Figures 1-3):

- a comprehensive depiction of the in- or outward beveling of the involved bone structure (e.g. the skull);
- the study of the location of bone fragments;
- the study of the fracture pattern.

The role of PMCT techniques in differentiating entrance from exit wound is limited if bone structures below the superficial defects are not involved [1-6].

Wound track and direction of the gunshot wound

In post-mortem imaging crucial information about the course and direction of the trajectory can be obtained through [1-6, 9](Fig. 4-7):

- the analysis of tissue damage along the track represented by gas bubbles and haemorrhage;
- the characteristics of bone defects, the location and distribution of bone/projectile fragments. The direction of the trajectory can be derived, infact, by analysing the numerical and spatial distribution of bone and bullet fragments, as already demonstrated for gunshotwounds to the head [4].
Of course, the wound track and the direction of the gunshot can be easily determined at PMCT by ideally linearly joining the entrance and the exit wounds or the entrance wound and the projectile in penetrating wounds (Fig. 6-7). Nevertheless, in some rare cases, the bullet may deviate by the linear course within the body and stop at sites totally unrelated to the original trajectory as a result of the impact with bone or interposed tissues (Fig. 8).

The role of PMCT techniques in delineating the wound track is limited without contrast agent injection, being indirectly indicated by the presence of gas bubbles and haemorrhage. The role of PMCT in determining the direction of the wound is limited if bone structures are not involved and multiple gunshot wounds are present [1-6, 9].

**PMCT KEY POINTS**

The contribute of PMCT to forensic investigations on gunshot wounds is related to its ability [1-6, 9]:

- to describe bone defects;
- to locate exactly bone and projectile fragments;
- to describe the distribution of bone and projectile fragments.

Other information can be desumed by the analysis of tissue damage indirectly indicated by haemorrhage, air bubbles along the track of the projectile.

The role of PMCT to forensic investigations on gunshot wounds is limited if bone structures are not involved and in cases with multiple gunshot wound in the same body reagion [1-6, 9].
**Fig. 1:** Axial CT image (a), multiplanar reconstruction (b) and volume-rendered 3D-CT reconstruction (c,d) in a case of single gunshot wound to the head (homicide). The entrance hole in the left parietal bone is well documented by characteristic bevelling of the inner table (b.) directed towards the inner cluster of bony and metallic fragments (d.). On the exit wound in the right side of the skull, the bullet caused a large loss of brain, leading to a skull shattering (a.). Note the pushed out bone fragments (c.).

Fig. 2: Multiplanar reconstruction in a case of a thoraco-abdominal gunshot wound (homicide). A penetrating wound is shown, with the projectile located anterior to the sternum. The entrance hole is located at the right chest wall (VIII intercostal space as documented by the gas bubbles in the subcutaneous tissues, and the costal fracture, with a bone fragment innerly displaced.

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Fig. 3: The CT reformatted image is referred to a case of homicide scanned following exhumation of the body 10 years after the victim's death and autopsy. The entrance and the exit wounds are distinguished by the study of the characteristic beveling of the skull defects. The entry wound is characterized, in fact, by a loss of substance, which appears conical or funnel shaped with bevelling of the bone surface in the direction of the exit wound; a reverse conic shape with beveling directed outwards is shown at the exit wound. According to these findings, the track and the direction of the projectile was defined. The bullet hit the victim in a cranial-caudal, slightly anteroposterior, direction entering through the parietal bone and exiting through the skull base.

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**Fig. 4:** Computed tomography axial images (a,b) and oblique multiplanar reconstruction image (c). Suicidal death: the images show multiple bones fragments within the haemorrhagic nervous tissue, with minute air bubbles embedded. The bullet’s intracranial course is directed anteroposteriorly, upwards and from right to left (a-c).

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Fig. 5: The findings of the first CT image examination: non-enhanced CT scans show: (a) an anterior linear soft-tissue defect (curved arrow), a haemo-pneumomediastinum (head arrow), a haemo-pneumopericardium, with suspected right ventricular wall laceration (short arrow); (b) a posterior linear soft-tissue defect (curved arrow); (c) a suspected left ventricular wall laceration (short arrow); (d) a laceration of the posterior basal segment of the inferior lobe of the left lung (short arrow) with the related haemothorax, and a small pneumothorax (long arrow).

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**Fig. 6:** Reformatted CT image along the trajectory of a retained projectile (penetrating gunshot wound) in a case of homicide). The entrance wound is located at the anterior chest wall (short arrow); the projectile is located in the soft tissues of the back (long arrow). Note the presence of haemopericardium, perihepatic and perisplenic haemorrhage, indicating the passage of the projectile through the heart, the liver and the spleen. The involvement of other structures could not be defined on PMCT.

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Fig. 7: CT axial images (a,b, c) referred to a case of homicide by a single gunshot wound to the head. The entrance wound shows the "classical" cone shaped appearance in a. Bone fragment with a particular distribution also indicate the direction of the trajectory. The figure b. shows tissue damage and the presence of gas embolism both caused by the passage of the projectile. In the image C. the retained projectile is evident.

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Fig. 8: The images are referred to a case of homicide due to multiple gunshot wounds: a)-c) 2D reconstructions show the track of the projectile delineated through the analysis of soft-tissue and bone lesions. The image a shows the entrance wound on the right anterior abdominal wall, indicated by the superficial cutaneous defect (short arrow). The image b. shows the presence of gas bubbles and haemorrhage within the soft-tissues of the right anterior abdominal wall (short arrow) and within the soft tissues of the back at the same level, but with different orientation in the plane. The image c. shows a bone defect in the right iliac crest, gas bubbles and haemorrhage and small bone fragment in the soft tissues of the right back, the last indicating the direction of the projectile. The image d. shows the track of the projectile deviated by the right iliac crest (long arrows).

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Conclusion

PMCT is a great complementary tool to autopsy in forensic investigations of single gunshot wounds to the head. PMCT without contrast agent injection is limited in cases with perforating wounds and without involvement of bone structures, and autopsy is still the gold standard in these fatalities. Nevertheless, 2D and 3D CT analysis non invasively has the potential to enhance forensic investigation and conventional autopsy in fatal cases with gunshot-wounds.
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References