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CASE REPORT

Pulmonary embolisation of bone fragments from penetrating cranial gunshot wounds

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Abstract Bone embolism is a very rare event that usually occurs in trauma-induced septic bone lesions, after bone surgery or after bone marrow transplantation, and normally remains silent. To our knowledge, there are no previous reports of bone embolism after a gunshot to the head. We describe a case of pulmonary embolism associated with bone fragments after a gunshot to the head in which bone fragments surrounded by leukocytes, interstitial and intra-alveolar oedema and haemorrhage around the embolised vessels, leukostasis and fat and bone marrow embolism suggest that the survival time from the gunshot was sufficiently long to allow changes in lung microcirculation and lung tissue.

Keywords Bone embolism · Pulmonary infarction · Gunshot to the head · Alizarin red S · P-selectin

Introduction

The lung blood vessels receive venous return from all the peripheral organs. For this reason, emboli arising in any part of the systemic circulation inevitably pass through the lungs; the lung being the organ in which most emboli are detected. Emboli usually consist of vascular thrombi, though they may be composed of other materials. Bone marrow and fat emboli, as well as air emboli, are often observed after trauma, resuscitation procedures and bone surgery [1]. Liver [2, 3], skin [4] and cartilage [5] emboli have been observed after massive trauma. Oily contrast medium has been detected in lung capillaries following a lymphangiography [6]. Bullet embolism in the pulmonary artery is a rare complication resulting from penetrating gunshot traumas [7, 8]. Most bullet emboli (80%) are arterial [9], frequently originating in the aorta, though the literature also contains cases of migration of venous bullet emboli to the right ventricle or pulmonary arterial tree as a consequence of gunshot wounds to the head [10, 11], abdomen [12] or extremities [13].

Bone embolism is a very rare event that usually occurs in trauma-induced septic bone lesions [14], after bone surgery [15] or bone marrow transplantation [16]. As bone chips do not usually occlude the vessel lumen, they do not cause severe disorders in the pulmonary blood circulation. Bone embolism is not normally followed by death; indeed, over time the endothelium covers the bone fragment, which in turn remains silent.

To our knowledge, there are no previous reports of bone embolism after a gunshot to the head, though emboli of cerebral tissue have sometimes been observed [17, 18]. We describe a case of pulmonary embolism caused by bone fragments after a gunshot to the head. The detection of the bone fragments in the lung vasculature and the associated histological findings demonstrate that survival following the trauma lasted a significant length of time.

Case report

A 26-year-old man was found lying on his right hip in a large pool of blood. He had been shot in the head with a 9× 21 calibre handgun.

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Gunshot wounds were found in his head, while bullet jacket fragments were found at the scene of the crime. A witness reported that they had been assaulted by a person approximately 30 min earlier. X-ray film of the skull revealed a wide compound fracture as well as metal and bone fragments.

Autopsy findings

The autopsy on the victim, a young male of medium build, was performed 72 h post-mortem. The body was 173 cm in length and weighed 65 kg. Post-mortem hypostasis on the back was very slight. The corpse did not present any injuries other than gunshot wounds in the head. An entrance hole was observed in the left parietal–occipital region, 161 cm from the left foot. An eccentric abrasion ring, without either soot or powder, surrounded the entrance wound. Once the scalp had been removed, a wound that ran tangentially to the outer parietal bone for 5 cm ("bone seton") was found to perforate the skull 2 cm behind the left ear. The wound continued tangentially to the inside of the parietal bone, exiting in the squama of the left temporal bone, above the left ear (Fig. 1).

A second entrance wound was located in the right mastoid region, 154 cm from the right foot. The exit wound presented an eccentric abrasion ring, which was smaller and was located in the left frontal–temporal region, 160 cm from the left foot. The gunshot entrance and exit wounds were documented using the fundamental data with regard to the wounds' morphological characteristics. The left side of the dura mater presented a laceration in the injured areas. Brain sections revealed oedema and congestion. The direction of the second gunshot was confirmed by the tunnel-like wound extending from the right parietal lobe to the left parietal lobe.

Fig. 1 Tangential perforating wound in the parietal bone with exit in the squama of the left temporal bone

There was diffuse subarachnoid haemorrhage. Both the right and left lungs revealed diffuse oedema and congestion. Toxicological tests for alcohol or drugs in the blood and urine were negative. No signs of intrasinus or intraventricular haemorrhage were observed.

Materials and methods

Samples were collected from the skin at the entry wounds, from the heart and from the lobe of each lung. Specimens were fixed in 10% formalin and embedded in paraffin, after which microtome-cut sections with a thickness of 2.5 μ were stained with haematoxylin–eosin (HE). Skin samples were sectioned and stained with Alizarin Red S (ARS), according to the method of Tschirhart et al. [19], in order to identify the barium in the gunshot residues (GSR).

Samples of the skin of the left parietal entry wound and of the left parietal muscle were stained for immunohistochemistry with P-selectin, using Target Retrieval Solution (Dako) for 20 min and a Dako Autostainer Instrument as follows: incubation in peroxide for 10 min, incubation with monoclonal mouse anti-human CD62P (P-selectin) clone 1E3 (Dako) diluted 1:50 in Dako REAL Antibody Diluent for 30 min, incubation for 30 min in Dako REAL TM EnVision TM Detection System, Peroxidase/DAB+, Rabbit/Mouse; incubation for 5 min in Dako DAB-AWAY, wash in distilled water and nuclear staining for 1 min with hemalaun.

Results

Histology sections of skin collected from the gunshot wounds, stained with ARS, revealed ruby red—ARS-labelled GSR particles composed of barium, as well as dark gunshot residues consisting of carbon and metallic fragments, deposited in and around the gunshot wound.

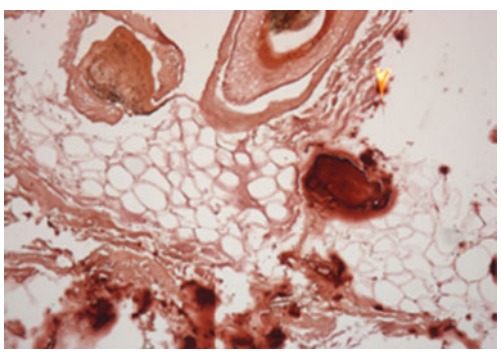

Fig. 2 Skin of the left parietal entry wound showing small fragments stained in orange red with ARS. The *largest one* shows a clear lamellar structure, identified as bone tissue

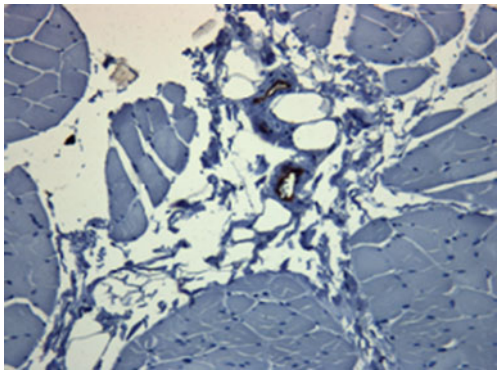

Fig. 3 Endothelial cells of the left parietal muscle tissue stained positive to P-selectin (×20)

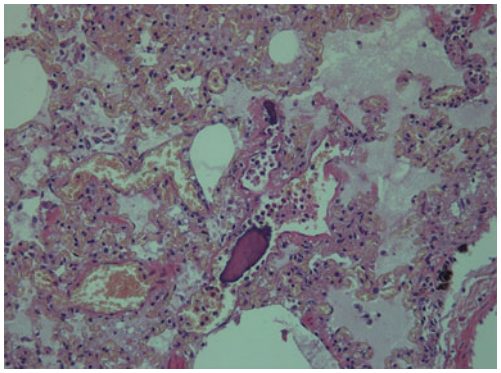

Fig. 5 A small bone fragment in a vessel surrounded by interstitial and intra-alveolar oedema, and leukostasis (×20)

Samples from the entrance and exit wounds of the tangential perforating wound revealed small fragments stained orange red with ARS (Fig. 2). These particles, whose structure was lamellar, were identified as bone chips. Endothelial cells of numerous subcutaneous vessels in the skin and in the muscle stained for immunohistochemistry were positive to P-selectin (Fig. 3), which corresponds to a survival of almost 15 min.

In the right lung lobe sections, numerous intravascular microscopic emboli, whose shape was similar to the fragments found in the skin entry wounds, stained purple with HE. The morphology revealed a lamellar structure and osteocyte lacunae, thus indicating that they were bone emboli, in some cases surrounded by leukocytes (Fig. 4). The bone chips occluded numerous small vessels which were surrounded by interstitial oedema (Fig. 5) and, occasionally, by areas of interstitial and/or intra-alveolar haemorrhage and clear leukostasis (Fig. 6). Very few vessels revealed the presence of fat or marrow embolism. The histological section of the left lung lobes revealed interstitial and intra-alveolar oedema, emphysema and atelectasis. The heart tissue displayed myocardial fibrosis and interstitial oedema.

Discussion

Bone marrow embolism has been reported in 6% of patients with trauma [20] and in 7% of 620 unselected autopsies [21]. Moreover, bone fragments have been observed in approximately 12% of patients with bone marrow embolism [22]. Bone fragment embolism is a rare event. A silent embolism of lamellar bone chips has been documented following the implantation of a hip endoprosthesis in two patients, who died respectively 3 months and 2 years after the operation [15]. Only one case was observed in a series of 9,000 autopsies [23], while 12 cases have been reported after bone marrow transplantation [16]. Bone embolism has also been reported as a consequence of osteomyelitis. Inflammation is not necessarily a prerequisite for bone embolism, although it might trigger it by breaking up the bone structure [14].

The case we describe is the first, to our knowledge, of bone embolism after a gunshot to the head. ARS, an anthraquinone derivative, may be used to identify calcium in tissue sections. The reaction is not strictly specific to calcium, since magnesium, manganese, barium, strontium and iron may interfere. It may therefore be used to identify

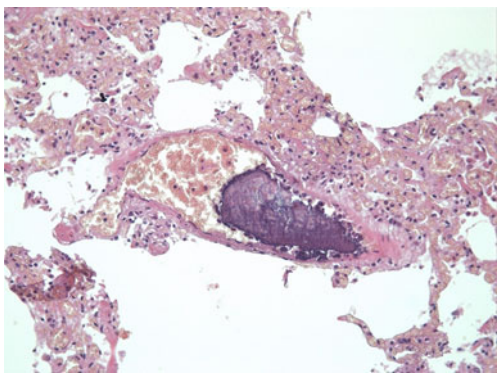

Fig. 4 Bone fragment occluding a vessel, surrounded by leukocytes (×40)

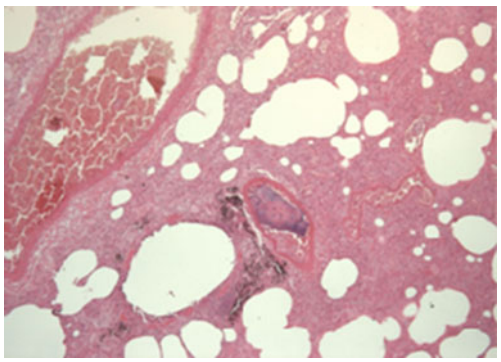

Fig. 6 A bone fragment occludes a small vessel surrounded by interstitial and/or intra-alveolar haemorrhage (×20)

the barium in the GSR. ARS stains barium in ruby red and calcium in orange red. The positivity found in the skin samples refers to the barium in the GSR, which is found in the dark gunshot residues consisting of carbon and metallic fragments, deposited in and around the gunshot wound. Larger fragments, not strictly related to the GSR deposits that were identified as bone chips stained orange red with ARS due to the calcium contained in the bone tissue. The bone chips found in the lung vessels were comparable in shape and structure to those found in the skin and were identified as bone emboli. Decalcification of the lung samples was not necessary owing to the thinness of the section (2.5 μ). Bone embolism is an important forensic sign of vitality and survival following injury, while gunshot wounds to the head are typically fatal if the bullet crosses both brain hemispheres, as in the case described here, or hits the brain stem, which controls the basic vital signs. The success of treatment depends on the time elapsed since the injury [24–27]. The force of contact impact by the bullets, particularly of the tangential perforating wound in the left parietal bone, presumably pushed microscopic fragments of bone forcibly from the edges of the entry or exit wounds into the venous channels. These fragments are then likely to have been transported by the circulation, during the agonal period of survival, towards the lungs, where they may have completely occluded the small pulmonary arterial blood vessels. The high number of bone fragments found in the pulmonary vessels implies an extensive degree of injured bone fragmentation, which is in keeping with the tangential contact due to friction in the tangential perforating bullet wound with the left parietal bone.

Bone chips surrounded by leukocytes, interstitial and intra-alveolar oedema and haemorrhage surrounding the embolized vessels, leukostasis, fat and bone marrow embolism all suggest that the survival time from the gunshot was sufficiently long to allow alterations in lung microcirculation and in lung tissue. This hypothesis is supported by the P-selectin expression in the endothelial cells of the injured skin vessels, since the reaction takes some minutes to occur, as well as by the large amount of blood lost by the man before death.

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