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Distinctions between *Peri* and *Postmortem* Bone Lesions on a Burnt Body in the Aftermath of a Road Accident

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Abstract

The judgment of "sudden death" or "non-sudden death" is important in forensic diagnosis. Although Postmortem Computed Tomography (PMCT) is widely used to determine the course of death, the judgment of the origin of the bone lesions between burns or trauma is fundamental.

Here, we present a case of a "light vehicle *vs*. light vehicle" road accident, complicated by a near-immediate combustion of the vehicle and the imprisonment of the victim. Both PMCT interpretation and autopsy concluded that the death was consistent, resulting from burn injuries and possible smoke poisoning.

We then propose to review the diagnostic bone characteristics specific to thermal injuries. The distinction between these lesions of different origin is especially important in cases of suspected third-party death, where it becomes essential to recognize thermal lesions in order to distinguish them from lesions of other origin.

Keywords: Postmortem computed tomography; Autopsy; Burn lesions; Diagnosis

Introduction

Virtual autopsy is the application of medical imaging techniques in forensic science. It's essentially based on the use of PMCT (postmortem CT scan) and 3D reconstructions. It can be employed as an independent observation tool, blind to the forensic autopsy, or at best in consultation with the coroner, allowing in pre autopsy the guidance of researcher in post autopsy further in the understanding of certain component. The radiologist then must determine the potential causes of death and differentiate them from postmortem CT scan artifacts.

PMCT thus raises awareness of forensic investigations, it allows evidence to be collected in a non-destructive way and enable the body to be preserved in a "virtual form" for possible future investigations. PMCT shows an important sensitivity for bone lesion's evaluation and is therefore a significant tool in clarifying the events leading to the subject's death.

Here, we present a case of a "light vehicle *vs*. light vehicle" road accident, complicated by a near-immediate combustion of the vehicle and the imprisonment of the victim. One must determine the patient's cause of death, i.e. polytraumatic origin or by calcination. We will tackle bone damages characterization in order to determine whether they are peri or postmortem, during a complementary autopsy and CT scan analysis.

Case Presentation

Casuistic

According to the provided information, the 20-year-old deceased was allegedly the victim of a "light vehicle *vs*. light vehicle" road accident. According to the witnesses of the accident, she was driving in the left lane in a 110 km/h limited area and was reportedly struck by another light vehicle slaloming between the lanes. The victim's vehicle supposedly caught fire without the witnesses being able to extract her from it.

The dispatched emergency rescue on site did reportedly not perform any resuscitation manoeuvres. A Jane Doe's death certificate has been issued the same day.

Prior to the autopsy, a full body CT scan without injection of contrast agent was carried out

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Figure 1: Flaking and cortical fissures.

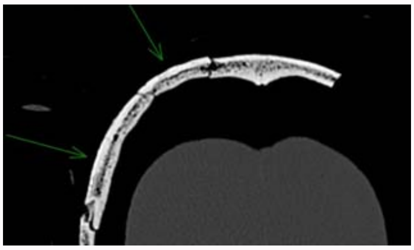

Figure 2: Split dipole sign or fracture of the spongy bone in the dipole.

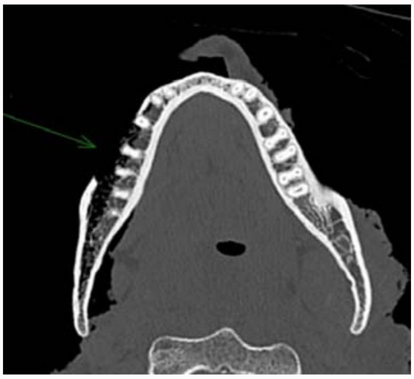

Figure 3: Decortications of the right external face of the mandible body.

with fine bone sections reconstructions for the purposes of the study.

I/Postmortem CT scan

The CT scan acquisitions were then exported to the PACS (Picture Archiving Communication System) before being interpreted by a radiologist.

Facing the skull was found a bursting of the calvaria associate with the existence of fractures and cortical fissures, a predominant flaking at the vault with bare auras of the dipole and a split dipole sign, all related to fractures of thermal origin (Figure 1,2).

A decortications site was also observed vis-à-vis of the external face of the right side of the mandible body, with exposure of the spongy tissue, associated with significant loss of tissue substances affecting the right hemiface (Figure 3).

A fine linear scattered hyper density was found at the surface of the brain related to the desiccation and shrinking phenomena of the encephalon. In addition, a sagging burst of the left eyeball and dental

Figure 4: Bursting of the calvaria, dental crowns of the incisors of the upper dental arch and decortications of the right external face of the mandible body.

Figure 5: Radius oblique fracture, ulnar longitudinal fracture and overall amputation of the fingertips.

crowns of the incisors of the upper dental arch were also observed (Figure 4).

Reconstructions on the hyoid bone showed a bilateral ossification defect between the body and the large horns of this bone without associated traumatic lesion. Similarly, no traumatic damage was found facing the thyroid cartilage.

Thoracic analysis revealed the existence of diffuse ground glass opacity of the entire pulmonary parenchyma combined with rare interlobular cross-linkages, not gravito-dependant, related to a potential pulmonary edema.

Looking at the abdomen, we found a typical postmortem aero-liquid gastric distension and a non-specific effusion blade in the pouch of Douglas.

The overall analysis indicated a pugilist position and showed an oblique fracture of the distal third of the left radius in relation to a significant loss of subcutaneous substance and a left distal ulnar longitudinal fracture.

The patient also exhibited distal phalanges loss and numerous bilateral limb fractures involving metacarpals and phalanges of the upper limbs (Figure 5).

In the end, we did not find any traumatic-looking fracture over the entire bone framework. Deep substances losses with exposed bones were predominant in the anterior region of the cephalic end, thorax, abdomen and lower limbs and diffuse in the upper limbs particularly in the forearms, and were associated with thermal skin tears of the lower limbs.

Figure 6: So-called pugilist position on upper limbs.

Figure 7: Oblique fracture also called "bec-de-fûte".

Figure 8: Burst skull associated with decortications areas of the external table and exposure of the dipole.

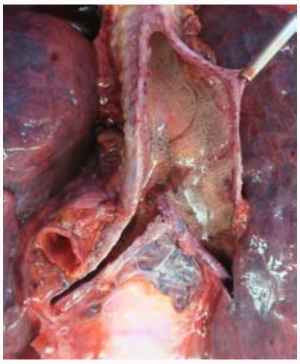

Figure 9: Black soot deposit and foamy secretions on pulmonary oedema in the trachea.

This investigation also revealed the existence of radio-opaque elements such as jewelleries - which could subsequently be used for the victim's identification – the absence of radio-opaque dental care, and the exclusion of the presence of ballistic elements, although this is not the context in this case.

With a perspective of further identification, we pointed out that the morphology of the frontal sinuses remained exploitable despite the bursting of the cranial vault and that comparative odontological analysis was conceivable regardless the bursting of some dental crowns.

In summary, the radiological examination established as immediate cause of death (fatal pathological lesions) a probable diffuse pulmonary edema which could be part of an inhalation syndrome. On this charred body, Grow-Glassman's score was evaluated at 3 (cf. article) based on the bursting of the skull vault, the numerous substances losses and the thermally induced fractures. Eventually, no traumatic fractures were found.

II/Forensic autopsy

Following the imaging examination, an autopsy was carried out. The corpse in question was female, of average corpulence, 166 cm of height and 69 kg of weight. Charred clothing fragments and a partially melted metal belt buckle were identified. A yellow metal necklace with a pendant set with eight translucent stones arranged horizontally and a ring set with one white translucent stone on the finger of the right hand were uncovered.

The cadaveric phenomena were well established, with the presence of reddish, settled, posteriorly laid-out lividities, which faded when the skin is pressed. No rigor mortis persisted. There were no signs of putrefaction.

There was an almost diffuse state of carbonization of the body sparing part of the lumbar area and the posterior face of both thighs. In connection with the thermal phenomena, a retraction of upper limbs (the so-called pugilist position, cf Figure 6), an oblique fracture of the left radius also called "bec-de-flûte" (Figure 7) and of all the phalanges, extensive areas of skin tears involving the cephalic end, the anterior thoracic wall, upper limbs and both thighs were revealed.

In addition, no recent traumatic tegumentary lesion was identified, subject to the state of carbonization of the body.

The autopsy performed on this corpse revealed a body with almost diffuse carbonization lesions with artifacts in link with thermal processes actions dominated by a burst skull (Figure 8), an oblique fracture of the left radius and numerous skin tears sites.

We also highlighted an asphyxia syndrome (diffuse visceral congestion, pulmonary edema, pleural petechiae) and a soot inhalation in the subglottic airways testifying to the breathing of the deceased in the fire fumes and reflecting the living status of the victim at the time of the fire (Figure 9).

The carboxyhemoglobin level measured during the autopsy on peripheral blood was 6.2% and therefore discreetly increased in a non-smoker deceased. Cyanides blood concentrations were <0.2 µg/mL, which allowed to exclude an intoxication.

No traumatic lesions related to the road accident were observed. We concluded that this autopsy report was consistent with a death resulting from burn injuries and possible smoke intoxication.

Regarding identification, the corpse was a leukodermal subject of female sex, of medium build (measuring approximately 166 cm and weighing 69 kg), of adult age, with no detectable surgical stigma. The victim was wearing a yellow metal necklace with a pendant set with eight translucent stones and a ring set with a translucent stone on a finger of the right hand. The anatomopathological expertise did not show an immediate microscopic cause of death.

There was diffuse vascular congestion with a bilateral pulmonary edema, accompanied by a hemodynamic state of shock. There was no evidence of soot deposition in the lower respiratory tract.

This unspecific microscopic observation may result from diffuse cutaneous burn lesions in relation with inhalation of toxic fumes. The death occurred on a previous non-pathological subject who may have contributed to the death.

Discussion

The temperatures found in a car in the event of a fire are often high, estimated at 1,000°C to 1,100°C according to experiments [1]. It has also been proven that the window shattering – during an accident or due to thermal causes – leads to a draught which results to a local increase of temperature from 600°C in an enclosed environment to 1,100°C.

In our case of a victim who was trapped in her vehicle, the CT scan carried out prior to the autopsy revealed numerous recent bone lesions throughout the skeleton as well as the presence of pulmonary edema which could be part of an inhalation asphyxiation syndrome. The autopsy showed a state of diffuse charring associated with a pugilist's position, loss of distal phalanges and diffuse skin defects, particularly on the vertex.

An asphyxiation syndrome with diffuse vascular congestion, pulmonary edema and pleural petechiae was also found, in association with soot inhalation in the subglottic airways in relation to smoke inhalation and therefore with the victim's living status at the time.

Toxicological analysis did not indicate any higher-than-normal levels of CO or cyanides. Lastly, the anatomopathological examination confirmed the presence of diffuse pulmonary vascular congestion, which could also be linked to an asphyxiation syndrome.

The case of the victim found incarcerated and charred in her vehicle thus raised several questions: was it a polytraumatized victim unable to escape from the vehicle then secondarily burnt, or a victim neutralized by the fire fumes then secondarily burnt. Symes et al. [2] has described diagnostic bone characteristics specific to thermal injuries. Longitudinal fractures are very common, and follow the architecture of haversian tubes. For some authors, they only occur on dry bone. Helical fractures, as seen in this case, represent a variant of longitudinal fractures (Figure 5). Transverse fractures, also very common, perpendicular to the haversian architecture and therefore parallel to the orientation of the Volkmann tubes. They are due to the perpendicular arrival of heat on the bone and can thus be seen just as much as transverse fractures, particularly on the upper limbs when the pugilist's position is set. For some authors, they are especially visible on greenstick fractures [3]. Oblique fractures have arciform diaphyseal ends associated with beveling between the cortex and the spongy bone; they are also called fractures in "bec-de-flûte". They reflect the evolution of an arciform fracture with detachment of the bone (Figure 5, 7). Decortications or delamination are areas of the cortical bone that are detached under the effect of heat, exposing the dipole of the skull by crumbling of the outer table (Figure 3) or the spongy area opposite an epiphysis. The CT scan analysis can then be used to visualize the fracture lines within the cancellous bone, parallel to the cortical surfaces, known as the "split dipole sign" in relation to the calvaria (Figure 2). The reticulated fissures are superficial cortical fissures (Figure 1) - in a network with more or less tight and regular meshes - most often on wide areas with little thickness of soft tissue such as the skull, which would indicate regions less exposed to the heat.

The topography of the evaluated regions is also important and has specific features to be known.

The cranial vault can be subject to a "pressure cooker" effect and explode due to the internal pressure of water steam (Figure 4,8) [4]. On the skull, the fissures readily appear facing the temporal or frontal regions, as these are the most exposed. These fissures are mainly bilateral, with irregular and jagged edges. They may only concern the external table or both tables. The occurrence of a pseudo extradural hematoma is ordinary but important to know whereas a subdural hematoma will have a perimortem meaning. It important to know that toxins concentrations within these extradural hematomas seem to be particularly reflective of the perimortem toxins concentrations.

Thermal amputations are frequent in the presence of high temperature or a sustained heat source; they are due to disarticulations or thermal fractures. The upper limbs often appear in major retraction with thermal fractures of the hands and wrists (Figure 5). The thorax and abdominal-pelvic cavity appeared well preserved. Due to the anterior position of the teeth and their thinness, the incisors are the most exposed to alterations. According to Quatrehomme et al. [5], the enamel cracks as early as 150°C and fractures around 500°C, the unexposed dentine cracks around 600°C before disintegrating around 800°C [6].

Based on all of these considerations, we assess that bone lesions found on this corpse were of thermal origins without any obvious traumatic bone lesions.

Conclusion

This case illustrates the importance of differentiating peri- and post-mortem lesions in the context of calcination and particularly the complementarity between autopsy and CT scan data. The analysis of this case shows that most of the bone lesions were of thermal cause without bone lesions of obvious traumatic appearance. Furthermore, the conjunction of low levels of carboxyhemoglobin and cyanides and pulmonary parenchymal lesions are also in favor of a thermal origin death.

The distinction between these lesions of different origin is especially important in the case of suspicion of death by the action of a third party; it then becomes essential to recognize thermal lesions in order to distinguish them from lesions of another origin. The combination of imaging and autopsy is then particularly effective in this regard.

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