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Forensic significance and inferential value of PMCT features in charred bodies: A bicentric study

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ABSTRACT

Post-mortem computed tomography (PMCT) is a diagnostic tool that provides essential information in forensic field. This radiological technique can play a pivotal role in personal identification, gunshot injuries, major traumatic injuries, child abuse, drowning asphyxia, embolism, COVID-19, sudden death, and charring cases.

Post-mortem imaging can be used to investigate charred bodies as it allows the forensic examiner to distinguish traumatic and heat injuries. PMCT images can also provide additional information to determine whether the individual was alive at the time the fire started.

In our bicentric study, we performed PMCT on 15 cases of charred bodies (10 males and 5 females) collected at the Florence University (Florence, Italy) and Catholic University of The Sacred Heart (Rome, Italy) before the external examination and/or full autopsy examination. In both the institutions, PMCT was performed through a Siemens SOMATOM 16-slice CT scanner (Siemens Aktiengesellschaft, Berlin, 2010).

The aim of the current study was to obtain unambiguous information that could help determine the cause of death by comparing our PMCT findings with the most recent evidence in the scientific literature. Our investigations focused on the evaluation of bone texture and differences from traumatic fractures, leading also to an improvement in the interpretation of some aspecific findings (e.g., soot) from the integration of the radiological information with the autopsy results.

The data obtained in our study support PMCT as a reliable diagnostic tool in the study of charred corpses and represent basic evidence for further applications of radiology in the forensic field.

1. Introduction

Victims of domestic fire and arson are frequent in forensic setting, representing a significant challenge for the forensic pathologist. One of the main issues is distinguishing between a death due to heat and a post-mortem cadaver carbonization. As charred corpses are often severely altered by the heat, time since death can't be estimated by traditional tools and the autopsy alone can usually find information of limited forensic value [1]. For this reason, in cases of charred bodies, a multidisciplinary approach resulting from the traditional autopsy - or the external examination alone - in combination with radiological, toxicological, and genetic analyses is usually recommended [2–4].

In these forensic cases, as said, it could be difficult determining whether the victim was alive when exposed to the heat (since carbonization can be also caused to hide signs of violent death) and if some specific injuries – like fractures – are due to heat rather than to

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mechanical forces [1,2,5,6]. However, this information is of substantial forensic value, since it is crucial to differentiate suicides and accidents from events with the involvement of third parties.

Traditionally, postmortem computed tomography (PMCT) has been recommended as a pre-autopsy investigation tool [7,8]. During forensic investigations (especially those of violent deaths) PMCT is not only a reliable and informative tool, but also has ethical, organizational, and economic advantages [9–11].

In scientific literature many recurrent PMCT findings in carbonized bodies are reported: heat hematoma (a friable, low-density, crescent-shaped hematoma, resulting of blood exudation from venous sinuses), "split diploë sign" (heat related separation of inner and outer table of the skull), thermal damage in the airways, presence of soot inside the upper respiratory tract, pulmonary edema, "*mottled appearance*" of the cortical bone ("*boiling*" of the bone marrow, with formation of hypodense areas), dense border sign (the dehydration of the soft tissue).

To the best of our knowledge, these parameters have never been classified on the basis of their significance from a forensic point of view, i.e. of their potential use to infer on questions of medico-legal value (vitality and traumatic nature of the lesions, personal identification) [1,2].

On this background, we retrospectively investigated cases of massive carbonization that underwent PMCT and forensic examination arrived at two Italian institutions. Our aim was to evaluate the role of PMCT in addressing the following three issues: (1) vitality at the time of the exposure to the heat; (2) mechanical vs heat-related lesions; (3) personal identification.

Furthermore, in our paper we discussed some radiological findings, typical of charred corpses, even if without forensic significance and not included in the three abovementioned categories (nonspecific radiological findings).

2. Materials and methods

This retrospective observational study was performed on 15 forensic cases of carbonization brought to two Italian institutions (the Section of Forensic Medical Sciences, Department of Health Sciences of the University of Florence, Italy; the Section of Legal Medicine of the Catholic University of Rome, Italy) between January 2017 and December 2022.

The cases considered were extracted from the databases of the two centers involved.

Cases meeting the following criteria were considered eligible:

1. charring of the corpse;
2. PMCT investigation performed prior to the necropsy-forensic investigation;
3. forensic examination (including external inspection of corpse and/or autopsy examination);
4. availability of data related to such elements as: sex and age of the deceased; known circumstances of the event; findings of the pathological-forensic examination (with relevant iconography); cause of death; radiological examinations performed.

In all carbonized cases a postmortem computed tomography (PMCT) scan was performed before the forensic pathology investigation (i.e., external examination and/or autopsy) using a 16-slice scanner (Philips Medical Systems, Best, the Netherlands, and Siemens Aktiengesellschaft, Berlin), with the following parameters: slice acquisition 1.25 mm, pitch 0.5, rotation time 0.5 s, tube voltage 120 kVp, tube current-time 400 mAs/rotation. No contrast medium was administered.

In each case image reconstruction was obtained at a slice thickness of 1 mm (0.6 mm increment), with soft tissue and sharp bone kernel.

In all cases the forensic pathologist was informed about the radiological PMCT findings before the forensic examination (full autopsy or external examination alone).

Age, classification of charring (suicidal/accidental/cadaver

Table 1
PMCT and autopsy findings in fire death investigation. *N.A., Not Available; E.E., External Examination.*

No.	Sex	Age	PMCT findings	Circumstances of death	Concordance PMCT/autopsy
1	M	36	Thermal subdural haematoma; dental decay (for victim identification)	Indoor fire	+
2	M	46	Thermal epidural haematoma; thermal bone lesions (skull vault) with small intraosseous gas collections in the marrow spaces ("*mottled appearance*")	Indoor fire	+
3	M	27	Cranial heat fractures with cerebral matter exposition; "*soot deposits*" in the respiratory tract; high attenuation of the lung surface ("*dense border sign*")	Car accident	+
4	M	28	Separation of the inner and outer table of the skull ("*split diploë sign*"); GGOs interpreted as signs of pulmonary oedema; thickening of the deep respiratory mucosa; "*soot deposits*" in the respiratory tract	Indoor fire	+
5	F	59	Separation of the inner and outer table of the skull ("*split diploë sign*"); metal denture (for victim identification); "*soot deposits*" in the respiratory tract	Indoor fire	+
6	M	59	Separation of the inner and outer table of the skull ("*split diploë sign*"); small intraosseous gas collections in the marrow spaces ("*mottled appearance*"); GGOs interpreted as signs of pulmonary oedema; high attenuation of the lung surface ("*dense border sign*")	Indoor fire	+
7	F	50	Small intraosseous gas collections in the marrow spaces ("*mottled appearance*"); high attenuation of the lung surface ("*dense border sign*"); internal genitalia -uterus- (for sex determination)	Car accident	N.A. (only E.E.)
8	M	60	Small intraosseous gas collections in the marrow spaces ("*mottled appearance*"); vital long bone fracture (femur)	Car accident	N.A. (only E.E.)
9	F	20	Dental analysis (for age estimation); internal genitalia -uterus- (for sex determination); thermal amputations	Indoor fire	+

(*continued on next page*)

Table 1 (*continued*)

No.	Sex	Age	PMCT findings	Circumstances of death	Concordance PMCT/autopsy
			with "*flute-mouthpiece*" ends (femur and tibia)		
10	F	8	Dental analysis (for age estimation); internal genitalia -uterus- (for sex determination); thermal amputations with "*flute-mouthpiece*" ends (humerus)	Indoor fire	+
11	F	4	Dental analysis (for age estimation); internal genitalia -uterus- (for sex determination); typical thermal amputations with "*flute-mouthpiece*" ends (tibia)	Indoor fire	+
12	M	75	Intracranial air; delamination of the skull vault ("split diploë sign") with disappearance of the external table; dental analysis (for age estimation); destruction of chest wall with high attenuation of the lung surface ("*dense border sign*"); thermal amputations with "*flute-mouthpiece*" ends (tibia)	Indoor fire	+
13	M	54	Tongue protrusion; "*soot deposits*" in the respiratory tract, and increased thickness of trachea wall; thermal ribs fractures; high attenuation of the liver surface ("*dense border sign*"); large soft-tissue loss with peritoneal interruption and evisceration; thermal amputations with "flute-mouthpiece" ends (tibia)	Indoor fire	+
14	M	58	Intracranial air; large soft-tissue loss; destruction of chest wall; small intraosseous gas collections in the marrow spaces ("*mottled appearance*")	Indoor fire	+
15	M	53	Intracranial air; delamination of the skull vault ("split diploë sign") with disappearance of the external table; dental analysis (for age estimation); tongue protrusion; thermal amputations with "*flute-mouthpiece*" ends of the extremities	Car accident	+

carbonization), place where the event occurred, results of PMCT and forensic investigations, presence of toxicological or genetic data were registered.

Two independent radiologists with more than ten years of experience, both blinded to the original PMCT and autopsy reports, were asked to examine all PMCT scans to flag the features of main forensic interest twice (the second time two months after the first) and their observations were compared. Two independent forensic pathologists with more than ten years of experience were then asked to retrospectively revise autopsy reports, when available, with the aim to verify whether PMCT lesions flagged by forensicesions, personal identificaradiologists were also detected at the autopsy.

PMCT features were then divided into four classes, depending on the forensic value of the information conveyed:

(A) Signs of vital heat exposure: radiological findings that suggest that the victims were breathing - and therefore alive - when the fire broke out (thickening of the respiratory mucosa, areas of Ground Glass Opacities in accordance with radiological criteria of the Fleischner society[12]); soot deposits in the respiratory tract.

(B) Differences between heat fractures and traumatic fractures: evaluation of the orientation of the fracture line (not perpendicular direction of the fractures when heat related) and the margins of the bone fragments (typically rounded when heat related) [1,2,6]. Flute-mouthpiece appearance (heat fractures involving the extremities with blunt edges and with complete exposure of the bone tissue due to the absence of the overlying soft tissues) [1,2].

(C) Elements for identification: macroscopic identifiers (like the reproductive organs for sex determination), presence of dental prostheses, preserved dental elements suitable for the DNA extraction.

(D) Nonspecific radiological findings: typical heat-related radiological signs are dense border sign (evaporation of tissues), pugilistic attitude (greater contraction of flexor muscles compared with extensors, which forces the limbs into flexion and the spine into extension), tongue protrusion (nonspecific sign of asphyxia also reported in corpse charring) [13].

3. Results

The cohort consisted of 15 forensic cases (10 males and 5 females). The age at the time of death ranged from 4 to 75 years (median: 50 years; mean value: 42 years). 13 cases were accidental charring, in one case it was suicide, while one case it was a cadaver carbonization (Table 1). The fatal event occurred in buildings in 11 cases and inside vehicles in 4 cases.

A full forensic autopsy and histopathological examination were performed in 13 cases, while in 2 cases the external examination alone. In seven cases toxicological testing were performed. Genetic analyses were performed in 8 cases.

In 13 cases where a full autopsy was performed a complete concordance between PMCT and autoptic findings was observed. The cause of death established by autopsy/external examination and toxicological analysis was in seven cases cardiac arrest due to heat, in seven cases severe carbon monoxide (CO) intoxication with detection of toxic concentrations of carboxyhemoglobin in the blood (COHb), while in one case characterized by extensive putrefactive phenomena the cause of death was not determined.

Intraobserver and interobserver PMCT evaluations coincided, and PMCT and forensic investigation results were fully concordant.

3.1. (A) Signs of vital heat exposure

In one case (7 %) the thickening of the respiratory mucosa was found. At the lungs, areas of Ground Glass Opacities (GGO) were observed in two cases (13 %). Soot deposits in the respiratory tract were detected in four cases (27 %).

3.2. (B) Differences between heat fractures and traumatic fractures

A vital long bone fracture (femur) was found in one case (7 %).

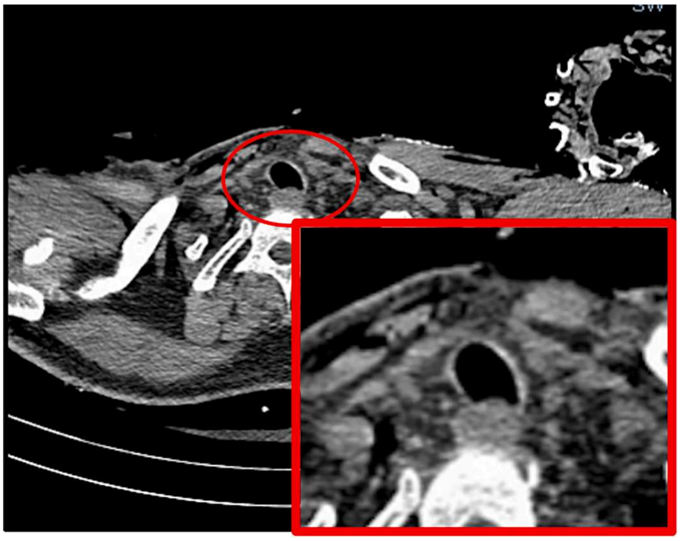

Fig. 1. Axial thoracic PMCT in burned body scans shows an inflammatory reaction on the respiratory mucosa (oedema) due to heat exposure, with soot deposits on the posterior wall of the trachea.

"*Mottled appearances*" of the bone marrow space was found in five corpses (33 %). Heat fractures with thermal amputations and "flute-mouthpiece" ends were observed in five cases (33 %). Multiple thermal ribs fractures were detected in one case (7 %).

3.3. (C) Elements for identification

In one case (7 %), dental decays were evaluated for identification purposes. Dental analysis was performed in three cases (20 %) to estimate the age of the victim. Visualization of the internal genitalia (presence/absence of uterus and adnexa) allowed sex determination in four cases (27 %) of extreme carbonization. The detection of metal prostheses contributed to personal identification in one case (7 %).

3.4. (D) Nonspecific radiological findings

PMCT examination showed subdural hematoma in one case (7 %) and epidural hematoma in another case (7 %). The separation of the inner and outer table of the skull ("split diploë sign") was observed in five cases (33 %). The disappearance of the external table was observed in two cases (13 %). The presence of intracranial air was found in three cases (20 %). In one case (7 %) characterized by cranial heat fracture, cerebral matter exposition was reported. In two cases (13 %) the destruction of the chest wall was observed. Tongue protrusion was found in two cases (13 %). In one case (7 %) a large soft-tissue loss with peritoneal interruption and evisceration was observed. High attenuation of the lung surface ("dense border sign") was observed in three cases (20 %) and the dense border sign of the liver was detected in one case (7 %).

Details of the results are available in Table 1.

4. Discussion

We reported a retrospective analysis of 15 severely carbonized bodies that underwent PMCT before forensic examination. In 13 cases where a full autopsy was performed, a complete concordance between PMCT and autoptic findings was observed. In the remaining two cases, where external examination alone was performed, PMCT allow to detect internal genitalia -uterus- for sex determination (case #7), and a vital long bone fracture -femur- that helped the forensic pathologist to determine whether the victim was alive when exposed to heat (case #8).

This data is relevant since, according to our results, PMCT can guide the forensic pathologists not only indicating meaningful lesions or foreign bodies [7,8], but also detecting signs of significant forensic interest (e.g., lungs features suggesting exposure to heat) that would recommend a full forensic autopsy rather than the simple external examination.

At this regard, it should be noted that in our cases we found a full concordance between PMCT and autoptic findings, thus confirming that PMCT can play a pivotal role in the analysis of charred bodies, also in cases where the external examination alone was performed.

As said, in our study PMCT findings were classified into four groups according to the main issues addressed:

(A) Signs of vital heat exposure;
(B) Differences between heat fractures and traumatic fractures;
(C) Elements for identification;
(D) Nonspecific radiological findings.

4.1. (A) Signs of vital heat exposure

As said, in forensic cases of charred corpses one of the main issues for the pathologist is to determine if the victims were breathing - and therefore alive - when the fire broke out.

Regarding that, in case #13 (Fig. 1), the tracheal wall showed an increase in density and thickness consistent with edema, that could suggest a hot gas inhalation (but – as GGO – is not specific). However, at the PMCT the lumen appeared particularly convex posteriorly as material of different density is observed, consistent with the deposition of hypodense particles on the walls of the trachea (soot deposits).

The radiological findings were confirmed at autopsy: abundant sooty material, edema and severe airway hyperemia were found in the

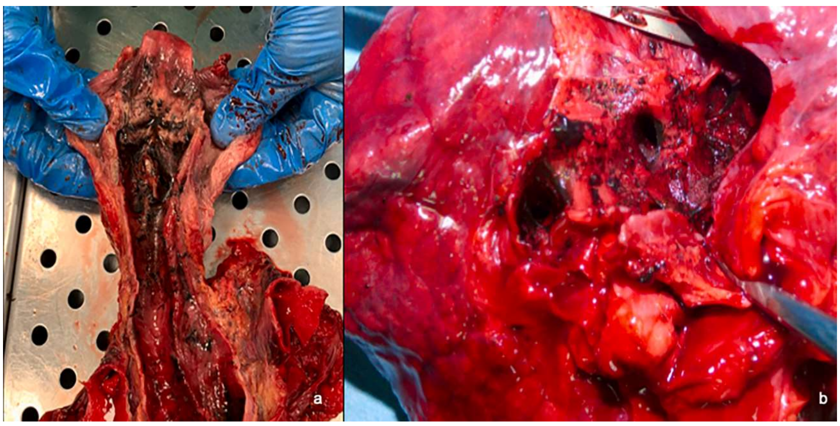

Fig. 2. Gross examination of the upper (a) and lower (b) airways shows heat injuries of the mucosa with soot deposits.

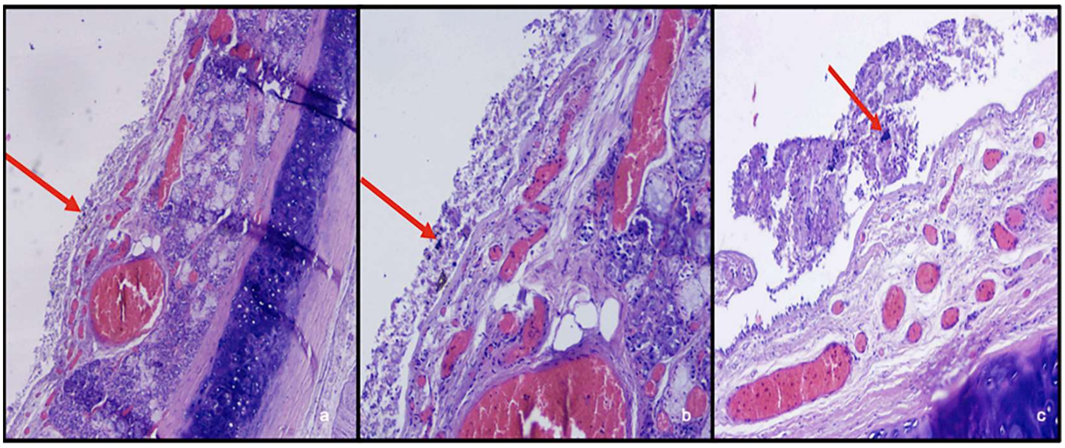

Fig. 3. (a–c): Histopathological examination (hematoxylin and eosin) of the airways shows soot deposits and pseudo-globet cells (red arrows) (case #13).

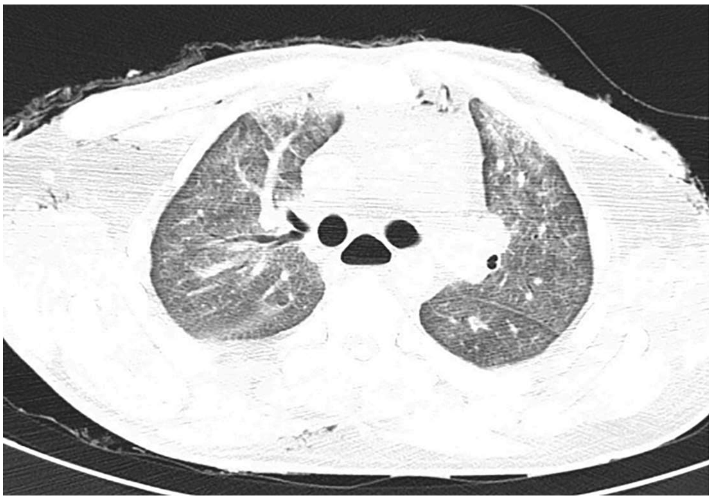

Fig. 4. Axial thoracic PMCT in burned body scans shows bilateral and multifocal ground-glass opacities, consolidations and a significant thickening of the bronchial mucosa.

tracheal lumen (Fig. 2a). Moreover, carbonaceous material was observed in the lower respiratory tract (Fig. 2b).

Sooty material was also detected at the histopathological examination. Increased thickness of the tracheal mucosa and amorphous material deposits (soot) on the tracheal lumen were also confirmed microscopically (Fig. 3).

To the best of our knowledge, this paper is the first to report the PMCT image of this finding, that is of great interest from a medico-legal point of view, since it strongly suggests the inhalation of fumes. This feature always needs to be confirmed at the macroscopic and microscopic analysis, but, if PMCT is performed before forensic examination and this image is found, full autopsy and toxicological testing (to verify CO poisoning) should be strongly recommended.

Traditionally, the PMCT feature recurring in the chest reported as the most typical is the pulmonary oedema, typically diffuse ground glass opacities [1]. PMCT ground glass images found in our cases were compared with CT ground glass opacity images in the living person reported in scientific literature [1,14,15]. The observation of GGOs on PMCT examinations of the lungs is frequent; GGOs are a non-specific finding since they can occur in several contexts, being the expression of many pathological processes leading to death and converging in pulmonary oedema, or, for example, being related to pulmonary infections (e.g., COVID-19 pneumonia) or are normal post-mortem changes (e.g., hypostasis) [1].

That being said, GGO radiological appearance should be carefully analyzed with particular regard to the localization of pulmonary areas (e.g., hypostases are localized according to a gravity gradient) and to their characteristics. Indeed, – for instance – the distribution of GGOs within the pulmonary parenchyma is different for example in cases of drowning [16] or in subjects with interstitial pulmonary infections like COVD-19 pneumonia [17]. An expert forensic radiologist should be confident in distinguishing typical appearances of heat related pulmonary oedema and many other causes of GGOs in the lungs.

However, since oedema is absolutely nonspecific, also other pulmonary features should be considered in charred bodies.

Images should be reviewed in order to detect specific signs that can support the hypothesis of a heat-related edema. In one of our cases (case #4), in the context of diffuse GGO, a significant thickening of the bronchial mucosa was found (Fig. 4).

4.2. (B) Differences between heat fractures and traumatic fractures

In charred bodies, fractures can be due to heat or to traumatic forces (in particular blunt force trauma). Heat can disrupt bone structure directly (through chemical phenomena like dehydration, pyrolysis and calcination) and/or indirectly (because of the retraction of the soft tissues) [18–24].

First, when the so-called “soft tissue shielding” is lost, the well-known signs of marrow fat liquefaction (“mottled lucencies”) are found [2]. Other suggestive alterations are given by air bubbles inside

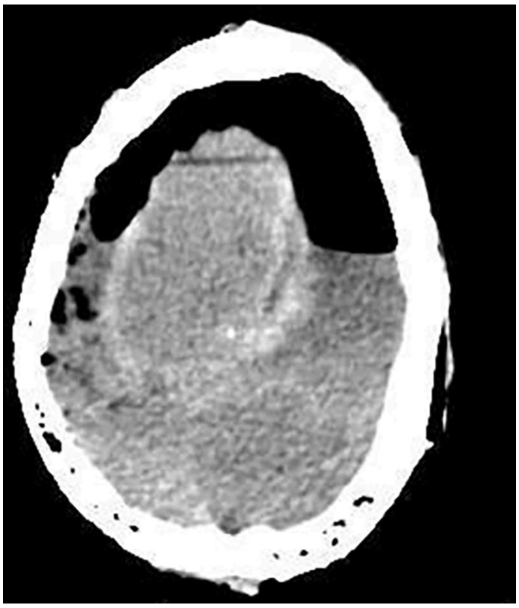

Fig. 5. Axial cranial PMCT image shows the presence of gases inside the bones.

the bones (Fig. 5), another change due to the heat exposure [2].

These features may mimicry pathological changes of the bone but are of low forensic interest. Instead, it is of great forensic interest to infer on the cause of a fracture found at PMCT and, in particular, to distinguish the lesions due to heat from those caused by mechanical forces (and that could suggest the involvement of third parties) [1,2,24]. Trans-diploic fracture may be observed in carbonized corpses and it is highly unlikely that they can be due to traumatic factors [1,2]. The cases presented here show the characteristic separation of the inner and outer tables of the skull, occasionally associated with the loss of the outer table or following a bizarre pattern (for instance, in Fig. 6 an occipital trans-diploic fracture resembling the lambdoid suture pattern may be seen).

The orientation of the fracture, its pattern and – when associated – the loss of the outer table can strongly suggest a non-traumatic cause. In general, a useful differentiation criterion is given by the orientation of the fracture line, since when it is not perpendicular to the bone surface the hypothesis of a non-traumatic cause is likelier (Fig. 6) [1,2,6].

Another suggestive parameter is given by the margins of the bone fragments, since they are typically rounded when they are separated from the main bone structure because of heat-related superficial cracking (Fig. 7) [24].

Margins of fractures are relevant also when they affect long bones. The extremity of exposed long bones fractures in the charred bodies typically show a flute mouthpiece appearance, a feature that can also be

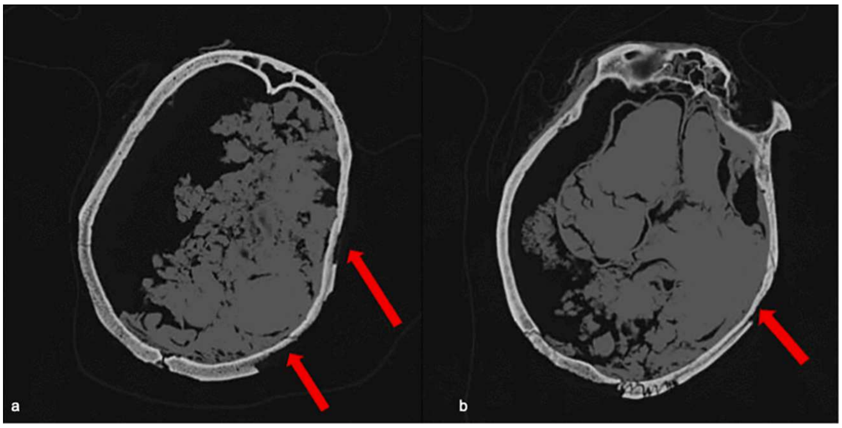

Fig. 6. Axial cranial PMCT (a, b) shows heat-related delamination of the skull with a longitudinal trans-diploic fracture (red arrows).

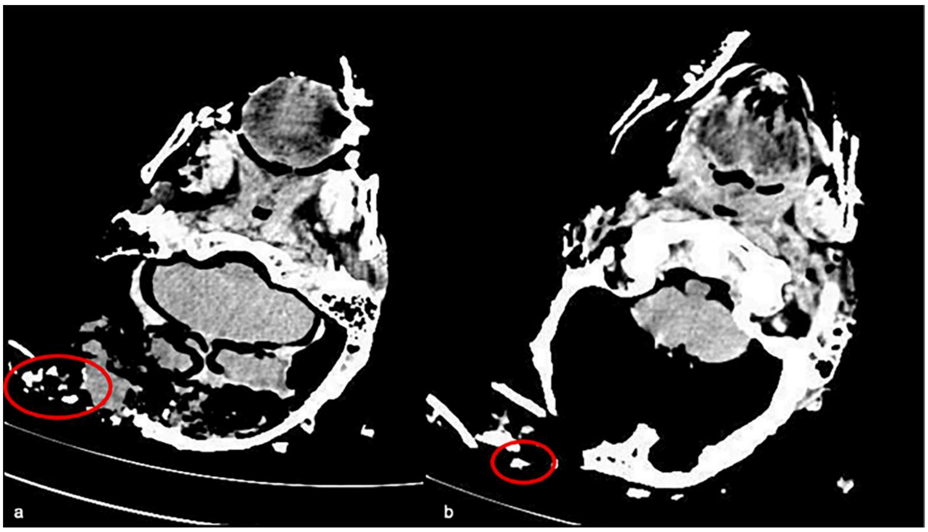

Fig. 7. Axial cranial PMCT (a, b) shows heat fractures of the occipital skull vault with blunt margins of the bone's fragments (red circle).

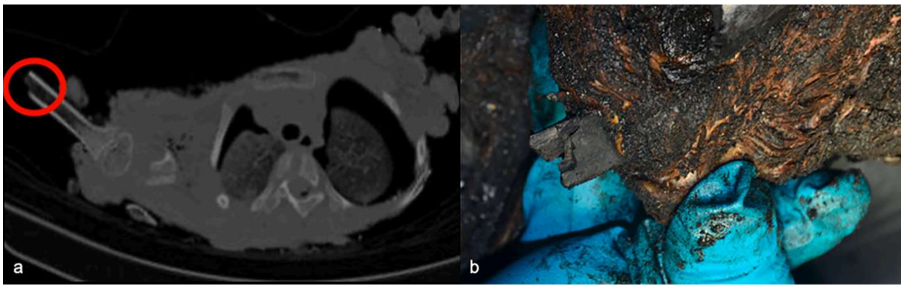

Fig. 8. Axial thoracic PMCT image shows a thermal long bone lesion (humerus) (a) (red circle). The autoptic image show typical "flute-mouthpiece" appearance (b).

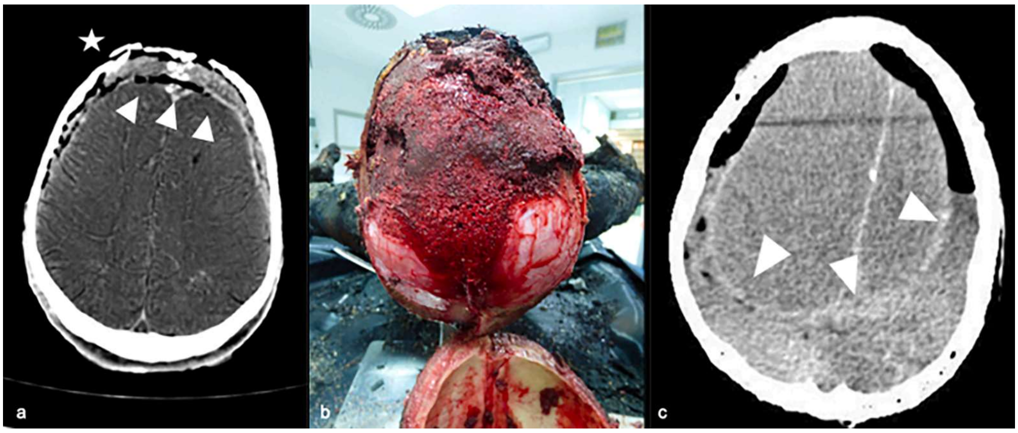

Fig. 9. PMCT scan of the cranial district shows a typical thermal epidural haematoma (a, c) (white arrowheads), together with a thermal fracture of the skull vault (a) (white star). Autopsy picture of the skull confirmed a thermal hematoma (b).

found in traumatic fractures [1,24]. In 2022, Divya et al. proposed that the margins and the color of these fractures ought to be regarded as relevant [24]. Indeed, as showed in Fig. 8, in case #10 the humerus fractures with a flute mouthpiece appearance presented a transverse part followed by a smooth, curved tract.

Instead, if the fracture had been caused by mechanical forces, it would have been likelier to find irregular, rough margins [24]. However, this morphologic parameter should always be analyzed together with color of the fracture, analyzed at the external examination with particular regard to the occurrence and the characteristics of a pattern of discoloration [24].

Finally, PMCT can give some information to infer on the cause of intracranial hemorrhages. Indeed, differences in density and shape can help to differentiate a heat (epidural) hematoma from a traumatic epidural hematoma (along with the presence/absence of a traumatic skull fracture). However, despite this, the main tool for the differential diagnosis remains the toxicological analysis to verify whether there are significant levels of carboxyhemoglobin in the hematoma blood (a typical sign of heat hematoma) (Fig. 9) [1,2].

4.3. (C) Elements for identification

Carbonization can easily conceal the identity of the victim, radically altering the visual attributes. At the autopsy this can still pose a challenge, since macroscopic identifiers (e.g., reproductive organs) may be strongly altered, and some important identifiers (e.g., intramedullary nails) can remain concealed [2,25]. In general, PMCT can overcome these limitations and may allow for the identification of the sex (through evaluation of other useful parameters like the circumference of the head, the bastion-prosthion and bastion-nasion distances, the foramen magnum, the dimensions, etc.) and the age (through the stage of development of teeth or wrist/hand bones) [26–30]. In charred bodies at PMCT reproductive organs may be often visualized (Fig. 10) together with other identifiers (e.g., protheses), thus obtain elements useful for

Fig. 10. Pelvic axial PMCT image shows female internal genitalia (a); Pelvic axial PMCT image shows male internal genitalia (b).

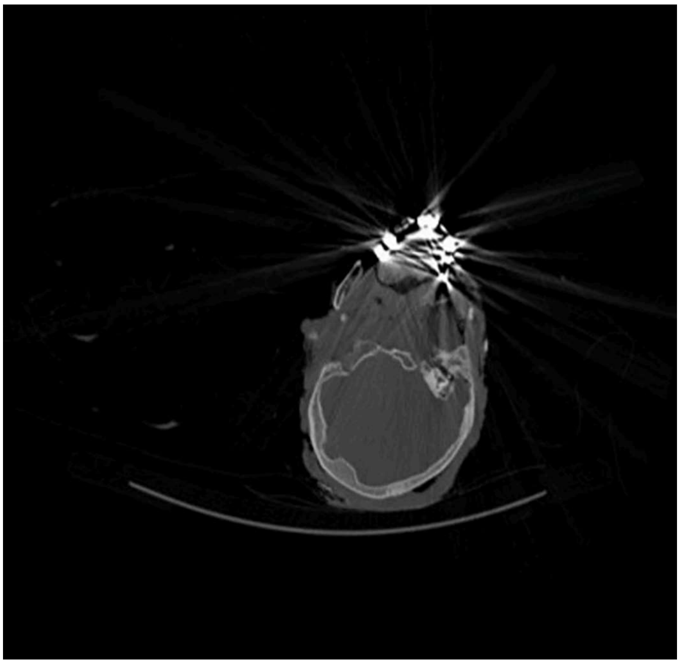

Fig. 11. Axial cranial PMCT shows multiple dental prostheses determining multiple artifacts.

personal identification (Fig. 11).

Moreover, 3D reconstruction can be performed on PMCT images, reproducing a clearer visualization of the facial structures (potentially enhanced adding a normal color to the superficial tissues of the face) (Fig. 12).

However, when the identity of the victim is uncertain or unknown, at least two primary identifiers, namely DNA and dental data (being fingerprints normally unavailable in carbonized bodies) should be used to identify the dead body [31]. PMCT of jaws yields radiographic images of teeth and dental treatments that can be easily and effectively compared to antemortem dental X-rays. Moreover, DNA can generally be retrieved in charred body, even from dental pulp of unaltered/intact teeth for the extraction of the dental pulp, leading to successful DNA profiling (Figs. 13 and 14) [32,33].

4.4. (D) Nonspecific radiological findings

In this category, we grouped all the features we found for which, despite being potentially related to carbonization, PMCT does not add any significant value to the traditional forensic routine.

For instance, shrinkage and dehydration of internal organs are well-known effects of thermal damage, as the “dense border sign” given by direct exposure to heat (Fig. 15).

At the same time, the loss of the chest wall with exposure of the thoracic viscera (Fig. 16) or the so-called “pugilistic attitude” (Fig. 17) are features for which PMCT adds no value to the common external examination.

A nonspecific PMCT sign in cases of charred bodies is the tongue protrusion through the dental arches and the lips. The mechanism behind the tongue protrusion is still discussed in literature, but the protrusion has been reported both for vital and for postmortem fire (Fig. 18) [13].

5. Study limitations

Limitations to the current study include the small number of cases that strongly limits our results. Moreover, before performing the

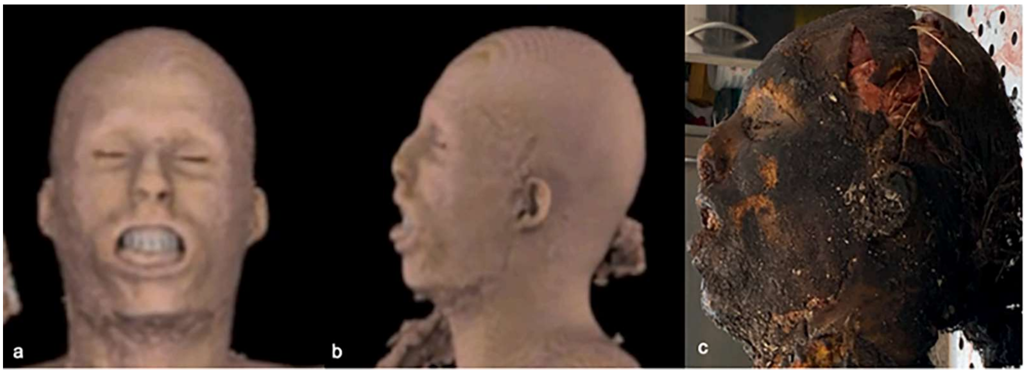

Fig. 12. PMCT 3D-rendered soft tissue image of the cranial district of a burned body (a, b); autopsy soft tissue appearance of a burned body (c).

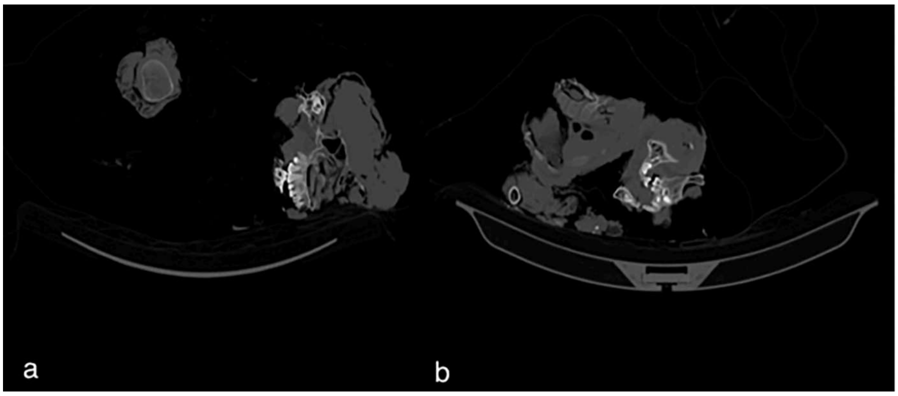

Fig. 13. Sagittal cranial PMCT detection of preserved teeth (a,b).

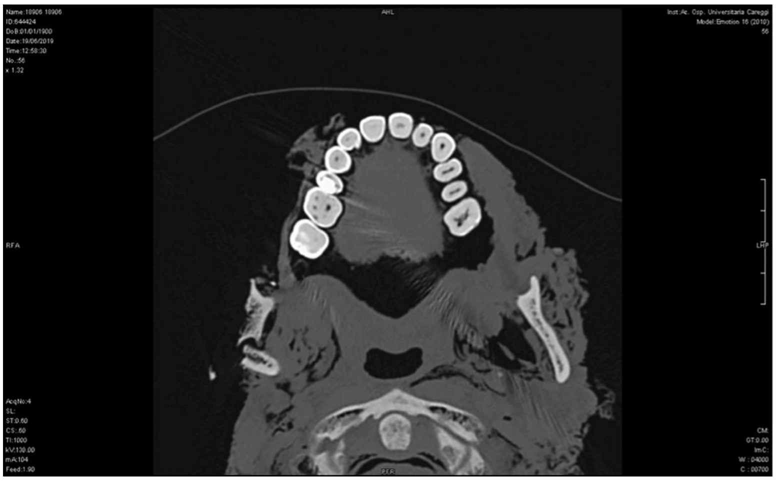

Fig. 14. Axial cranial PMCT detection of preserved teeth.

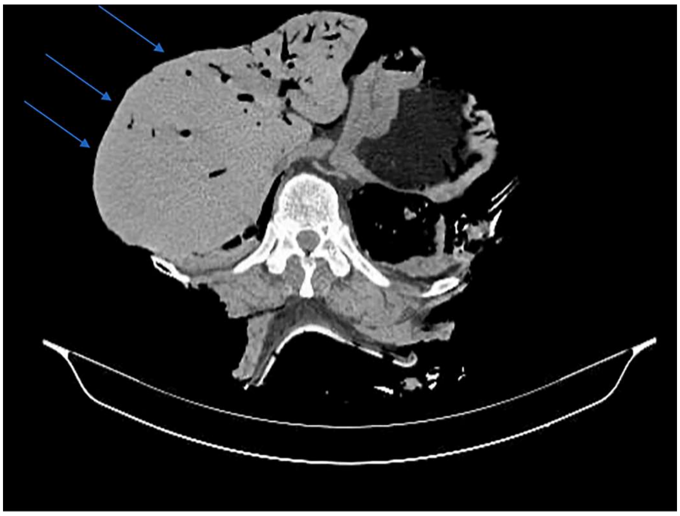

Fig. 15. Hepatic dense board sign (arrows).

autopsies, forensic pathologists were aware of the PMCT results. This may have led to more findings being identified because some lesions were already known from imaging, partially masking the actual benefits of PMCT. Also, in some cases, parts of the extremities could not be scanned because of bending deformations related to the limited diameter of the scanner.

6. Conclusions

PMCT confirmed to be a valuable tool to be used before the forensic examination. It may help the forensic pathologist in the decision-making process on whether to perform the external examination alone rather than the full forensic autopsy. Some features strongly suggest information of medico-legal interest regarding the manner of death but are highly nonspecific and deserve confirmation at the autopsy (e.g., presence of soot inside the airways). Other radiological findings provide information that can't be obtained at the autopsy (e.g., characteristics of fracture) that allow to differentiate between heat fractures and traumatic fractures. Furthermore, PMCT may enable the selection of appropriate teeth for genetic testing, limiting the risk of low-quantity/ low-quality DNA (and thus the risk of missed identification). However, some recurring findings at the PMCT add no significant value to the

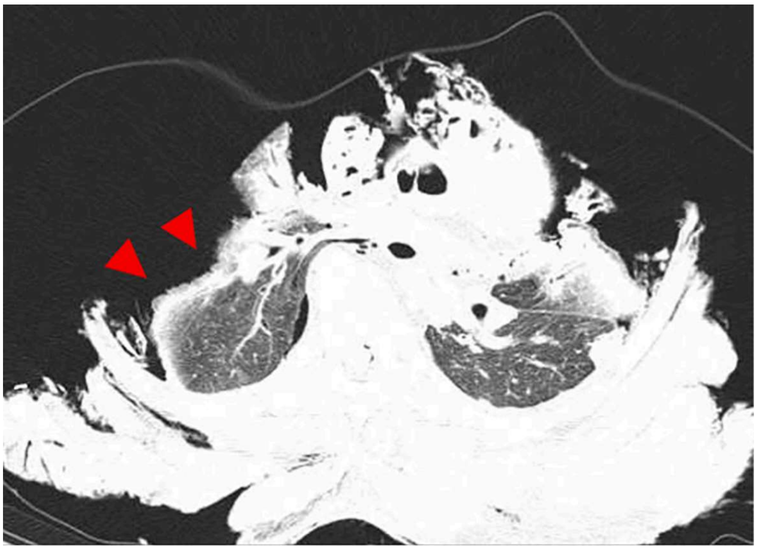

Fig. 16. PMCT scans show extreme thermal damage to the anterior chest and the soft tissue shielding on the posterior chest. Red arrowheads indicate the attenuation of the lung surfaces (dense border sign).

Fig. 17. "Pugilistic attitude" at external examination of the cadaver.

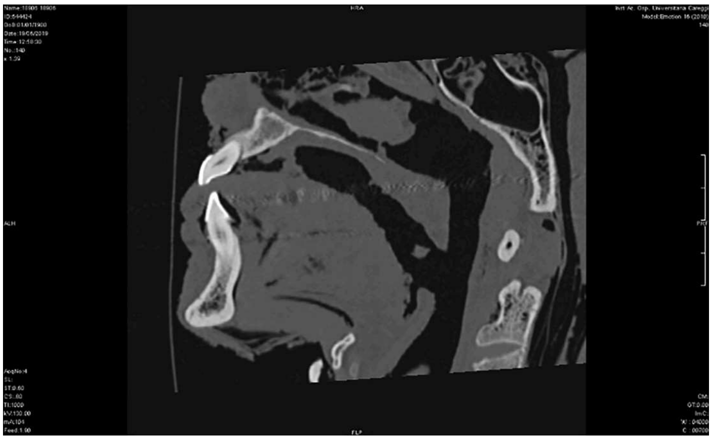

Fig. 18. Sagittal cranial PMCT detections shows the characteristic tongue protrusion.

traditional forensic process, and the pathologist must distinguish between radiological image with a strong forensic value and nonspecific findings. In conclusion, PMCT should be always considered in charred bodies to guide (and implement the information provided by) forensic examination and toxicologic and genetic testing.

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Data availability

Data are available upon reasonable request to the corresponding author.

Ethics approval, Consent to participate, Consent for publication

The study complies with the principles of Helsinki Declaration and with the requirements of European Union GDPR regarding consent regarding scientific publication of lawfully-processed fully-anonymized data.

CRediT authorship contribution statement

Antonio Oliva: Validation. **Simone Grassi:** Conceptualization. **Massimo Zedda:** Writing – original draft. **Linda Calistri:** Writing – original draft. **Francesca Cazzato:** Writing – original draft. **Valentina Masini:** Writing – original draft. **Matteo Polacco:** Writing – original draft. **Federica Maiolatesi:** Writing – original draft. **Ilenia Bianchi:** Writing – original draft. **Beatrice Defraia:** Writing – original draft. **Rossella Grifoni:** Writing – original draft. **Laura Filograna:** Writing – original draft. **Luigi Natale:** Supervision. **Martina Focardi:** Supervision. **Vilma Pinchi:** Validation.

Declaration of competing interest

All authors declare that they have no conflict of interest.

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