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The degree of destruction of human bodies in relation to the duration of the fire

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Abstract

The changes occurring during cremation were watched and documented in 15 undissected bodies to be cremated. It was found that at temperatures between 670 and 810°C the body showed the ''pugilistic attitude'' after about 10 minutes. After 20 minutes the calvaria was free from any soft tissue and fissures of the tabula externa could be noticed. The body cavities became visible after approximately 30 minutes, so that the organs were exposed. Forty minutes after cremation had started, the internal organs were severely shrunken and showed a net-like or sponge-like structure. After about 50 minutes the extremities were destroyed to an extent leaving only the torso which broke apart after 1–1.5 hours. The complete incineration of a human body took about 2–3 hours.

Keywords: Postmortem burns; Charred body; Thermic destruction of corpses; Duration of fire; Cremation; Heat fractures

1. Introduction

Medicolegal examinations of burned bodies mostly deal with questions concerning the identity of the victim, the vitality of the body before exposition to the fire and the cause of death. The relation between the duration of the fire and the degree of charring is only in rare cases of forensic importance [1–3]. Exact data are rarely found in literature and are mainly based on unsystematic observations made during cremations or descriptions of cases in which the approximate duration of the fire was known [4–6].

In his survey Madea [3] presented a case investigated by him and suggested collection

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of further observations. Continuing our study on burns of the skull [7] this paper deals in addition with the chronological course of the changes occurring on the other parts of the body.

2. Material and methods

2.1. Material

The burning of 15 undissected human bodies intended for cremation was witnessed. In all cases death had occurred for natural internal causes. The age ranged between 68 and 100 years and the sex ratio female:male was 8:7. Most of the bodies were of slim to medium constitution (Table 1). The bodies were cremated in coffins either made of 30 mm thick oak or 24 mm thick fir boards.

2.2. Cremation

The oven used for cremation is built up of three vertically arranged chambers: two cremation chambers and one ash chamber. The floor of the first cremation chamber, into which the coffin with the body is placed, consists of a wide grid of firestones. The chambers are separated from each other by movable plates so that the ashes of different persons cannot mix. For later identification of the ashes a firestone with a number engraved on it is put into the oven with every body. In the first chamber the body is cremated until it breaks apart (approximately 1 hour). By opening the partition plate the fragments fall into the second (previously emptied) cremation chamber where they are cremated for about another hour. Then after opening the next partition plate the still

Table 1

No	Sex	Age	Constitution	Temperature*	Duration of cremation (Within First Cremation chamber)
1	f	91	slim	720°C	70 min
2	m	70	medium	720°C	70 min
3	f	79	slim	750°C	70 min
4	m	73	slim	800°C	60 min
5	f	81	slim	670°C	50 min
6	m	85	medium	680°C	80 min
7	f	68	slim	780°C	80 min
8	m	74	sturdy	810°C	60 min
9	m	72	cachectic	740°C	70 min
10	f	91	slim	740°C	70 min
11	f	100	cachectic	730°C	50 min
12	f	86	slim	790°C	60 min
13	m	72	slim	800°C	80 min
14	f	81	cachectic	750°C	60 min
15	m	89	medium	790°C	60 min

*Mean of 6–8 single measurements performed at 10-minute intervals (first cremation chamber).

existing remains fall into the (previously emptied) ash chamber. After a cooling period of 1 hour, metal objects are removed by a magnet; then the remaining bones are ground and filled into an urn.

The fire is fuelled by natural gas with the power of the gas burner being adjusted by hand according to the degree of smoke development. In the first cremation chamber the flame nozzle is installed at the head end. Usually temperatures are around 800°C and are about the same in the first and second cremation chamber. The complete cremation process including cooling takes about 3 hours.

2.3. Method of observation

The cremation process can be watched through a 13×11 cm window at the head end of the first cremation chamber. The distance from the window to the skull of the body is about 1.50 m.

The oven temperature and the changes caused by the fire were recorded every 10 minutes. The destruction of the corpses was documented by photographs, as far as possible, using a Nikon AF-401 camera with an 28–200, 1:3, 8–5.6 objective by Tamron and the slide film Elite-400 by Kodak. The focal lengths of the objective used ranged between 120 and 140 mm. Partly the photographs were made with the light from the cremation chamber only, partly a flash gun (Nikon SB-26 with flash adapter cable SC-17) with TTL flash control (aperture setting 8, flash time 1/125 sec) was used in addition.

3. Results

The course of the changes caused by the fire followed certain rules. After up to 20 minutes the oak coffins were sufficiently burned to enable a sight of the body. In case 4, 6, 7 and 9, in which coffins made of 24 mm thick boards of fir wood had been used, the body could be seen 10 minutes after the beginning of cremation. The following times refer to the beginning of cremation.

3.1. After 10 minutes

- The body showed the ‘‘pugilistic attitude’’ [8].
- The skull-cap was free from any soft tissue, but not yet calcined. The soft tissues of the face were charred.
- In case 4 the soft tissue of the finger and metacarpal bones was already burned away.

3.2. After 20 minutes

- The calvaria was visible in all cases. Apart from case 2 fissures of the tabula externa could be noticed and/or the coronal or sagittal suture had burst. Only in the region of

the cheeks the bones of the face were still covered by sparse soft tissue remains. In 2 cases fractures of the mandibula occurred due to the fire.

- The skin of the anterior thoracic wall was burned; the chest muscles were charred and shrunken. In 8 cases the frontal parts of the ribs showed; in 3 of these cases the sternum and the costal cartilages were already destroyed so that the thoracic cavity was exposed.
- In the thoracic and abdominal region strong evaporation processes could be noticed; partly jets of liquid were spraying from tear-like openings of the body cavities.
- The skin of the arms was burned away; the outer surface of the muscles showed shrinkage and charring with the shrinkage being more pronounced on the lower arms than on the upper arms. Ulna and radius were partially uncovered. The hands were completely destroyed in 4 cases; in the remaining cases the calcined bones of the hands were still connected with the lower arms by charred soft tissue bridges.
- The lower extremities were difficult to see in most cases, as they were farther away from the observation window and the view was impaired by flames and smoke. Nevertheless it could be seen that the muscles of the upper and lower legs were charred, at least on the surface.

3.3. After 30 minutes

- The fracture gaps in the calvaria had considerably widened with boiling liquid, partly also more solid, crumbly material exuding from the gaps. In about half the cases the tabula externa disintegrated into fragments. The facial bones were calcined and showed only sparse soft tissue remains adhering to them, if any.
- In all cases the thoracic and abdominal cavity was exposed. From the body cavities exuded steaming, boiling liquid. The sternum was now destroyed in all cases. The lateral parts of the ribs became visible with the front sections being calcined and bent inward or outward (Fig. 1).
- The internal organs were blackened and shrunken. The intestine was protruding above the level of the abdominal wall. The anterior parts were charred whereas moist tissue could still be recognized in the more dorsal sections of the mesenterium.
- The arms showed small remains of shrunken, severely charred muscles. The lower arms were mostly reduced to the proximal sections; in one case the arms had been consumed completely by the fire.
- The tibiae and the distal parts of the thighs were largely free of soft tissue. The exposed sections of the long bones of the extremities were calcined and showed longitudinal fractures with rolled-up edges (Fig. 5).

3.4. After 40 minutes

- The calvaria had come off due to the fire so that the shrunken and superficially blackened brain showed. The bones of the face, which were now completely free of

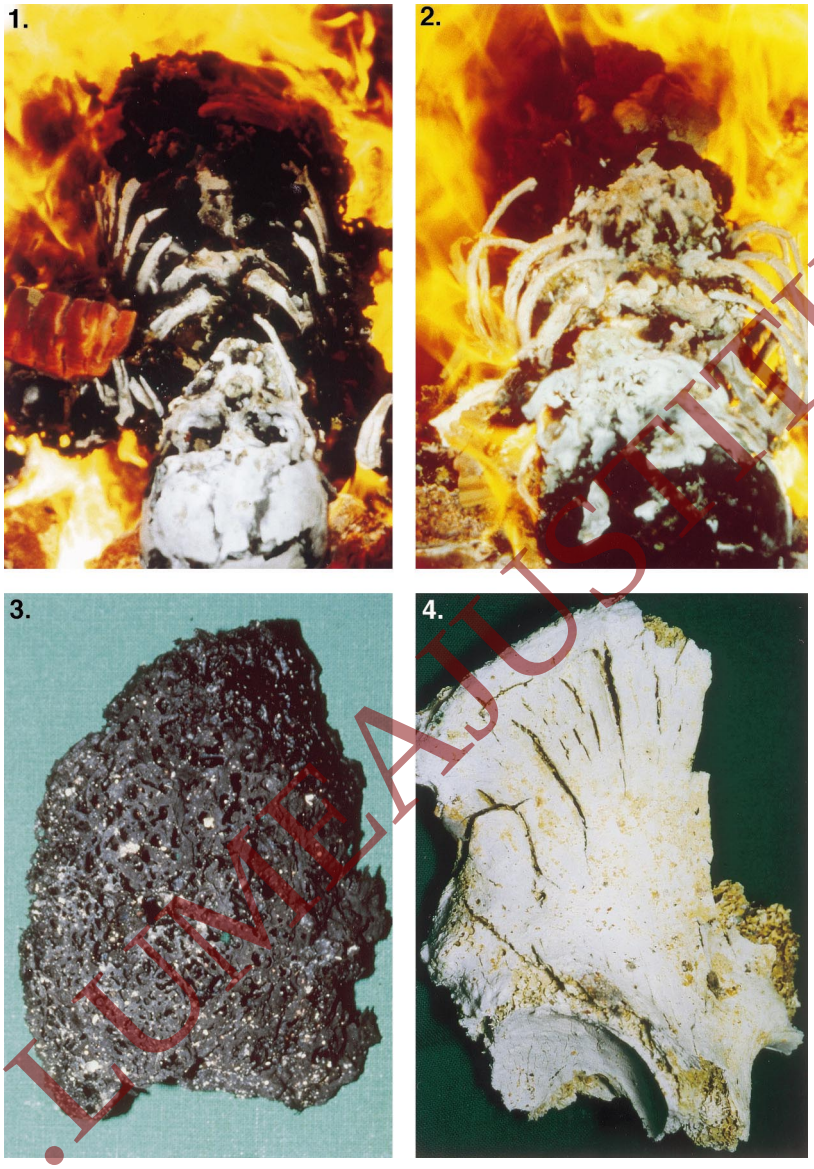

Fig. 1. After 30 minutes: The thoracic and abdominal cavities are exposed. The sternum is destroyed, the front sections of the ribs are calcined. The bones of the skull are calcined, the skull cap shows gaping heat fractures of the tabula externa.

Fig. 2. After 40 minutes: The ribs are free from soft tissue, calcined, twisted, and bent inward or outward. The base of the skull is exposed.

Fig. 3. Spleen with sponge-like surface, as commonly seen after about 40 minutes of cremation (autopsy finding in a charred corpse).

Fig. 4. Pelvic bone with parallel fracture lines found in the ash chamber.

soft tissue and calcined, disintegrated into fragments. The soft tissues of the neck were severely charred and shrunken; in half of the cases they were already completely consumed by the fire.

- The ribs were free of any soft tissue up to the posterior axillary line; they were calcined, twisted around their long axis and bent even stronger than described above (Fig. 2).
- The chest and abdominal organs showed further shrinkage and a sponge-like surface (Fig. 3). Intestine and mesenterium were reduced to a net-like structure. The evaporation process had strongly declined.
- Except in case 12 the lower arms were destroyed in all cases. The upper arms were largely free of soft tissue. The calcined humeri partly showed extensive longitudinal fractures and in almost all cases the head of the humerus was visible.

3.5. After 50 minutes

- The facial bones had essentially disintegrated. The base of the skull was exposed.
- Especially the upper parts of the vertebral column tended to hyperextension. The vertebral bodies were calcined and the intervertebral disks were missing. Continuity was maintained only by the remains of the severely shrunken muscles of the neck.
- The internal organs meanwhile showed considerable shrinkage. In most cases only the liver could still be recognized, although reduced to a sponge-like structure. The soft tissues of the small pelvis, which had been protected for a long time, were meanwhile consumed by the fire and the ilium showed only sparse rests of charred soft tissue adhering to the bone.
- The arms were completely destroyed.
- The thighs were reduced to calcined bone stumps.

3.6. After 60 minutes

- The destruction of the skull had progressed to an extent leaving only the central parts of the facial bones and the base of the skull.
- The intervertebral disks were destroyed; the vertebral column showed increasing dorsal flexion. In some cases the torsos were already headless.
- The internal organs were largely reduced to ashes. The soft tissues of the pelvis were totally consumed by the fire.

After a minimum of 50 minutes and a maximum of 80 minutes the torso broke apart. In our material there was no clear relation between the duration of the fire needed for destruction of the body on the one hand and temperature, material of the coffin as well as sex or constitution of the deceased on the other hand (Table 1).

4. Discussion

According to our observations it took about 1 hour at temperatures between 670°C and 810°C until the destruction by the fire had sufficiently proceeded for the body to break apart. The processes described above generally followed certain rules, but could vary by 10 to 20 minutes in the individual case.

Even at the end of cremation bone pieces could still be detected in all cases which could be recognized anatomically without doubt (Fig. 4). They were completely calcined and showed characteristic splits, partly with rolled-up edges of the fracture lines (Fig. 5). These splits were already noticeable during cremation in the first chamber and thus did not result from the cooling process, as described by Spitz [9].

The internal organs showed severe shrinkage in the observation period between the 30th and 50th minute, so that they looked like organs of a little child or a doll [10]. At this stage the organs increasingly displayed a bumpy surface and were finally reduced to a sponge- or net-like structure. After arriving at this point (so-called ''Zermürbungspunkt'' in German [11]) the completely desiccated tissues disintegrated into ashes.

Systematic observations of the cremation of bodies describing the chronological course of the changes caused by the fire were published by Günther and Schmidt [4], Richards [5], Eichenhofer [6], and Schweitzer and Eichenhofer [12]. Our observations largely correspond with the statements of these authors (Tables 2 and 3). Discrepancies

Fig. 5. Calcined fibula showing a longitudinal fracture with slightly rolled-up edges found in the ash chamber.

Table 2
Effects of the fire on the skull

Time	Günther and Schmidt [4] 1000°–1100°C	Richards [5] 680°C	Present study 670°–810°C
8–10 min	soft tissues of the face charred		skull-cap free of soft tissue, soft tissue of the face charred
13–16 min	forehead and vertex free of soft tissue, protruding facial bones calcined	bones of face showing	
20 min		skull showing	sparse soft tissue remains in the face, heat fractures of the skull-cap
20–25 min	severe shrinkage of soft tissues at the skull, calvaria breaks, brain superficially charred, destruction of prominent parts of the facial skull		
30 min			tabula externa of the calvaria crumbling
40 min			brain showing, bones of face begin to disintegrate
50 min			bones of face largely destroyed, base of skull showing
45–75 min	base of skull still intact, head sometimes severed from trunk		

Table 3
Effects of the fire on trunk and extremities

Body region	Time	Richards [5] 680°C	Present study 670–810°C
Thorax/ abdomen	20 min	ribs showing	thorax muscles charred, ribs and sternum showing
	30 min		thoracic and abdominal cavity exposed, organs blackened and shrunken
	40 min		shrunken, charred organs with bumpy surface
	50 min		organs largely consumed by the fire
Arms	10 min	arms badly charred	pugilistic attitude
	15 min	bones of arms showing	
	20 min		hands largely destroyed, ulna and radius partially showing
	30 min		hands and distal forearms burned away
	40 min		forearms completely consumed, upper arms largely free of soft tissue
	50 min		arms burned away
Legs	14 min	legs badly charred	
	20 min		carbonisation of muscles
	25 min	shin bones showing	
	30 min		tibia and distal femur free of soft tissue
	35 min	thighs and shins completely bone	
	50 min		calcined stumps of the thighs

are possibly due to differences in the construction and equipment of the cremation ovens. Under the cremation conditions of the cases studied by us the only gas burner was positioned at the head end of the first cremation chamber, as a result of which the upper parts of the body were consumed faster than the lower parts.

Comments regarding the relation between the duration of the fire and the degree of destruction were also made on the basis of individual observations [1,3,5]:

Westenhoeffer [1] reported on investigations conducted in the case of the embassy clerk Beckert who had killed an employee of the German embassy in Chile in February 1909 before setting fire to the embassy. Westenhoeffer performed tests regarding the question how much time it took to cremate soft tissue and bones. For these tests he used a female body which he cremated with the help of a coal gas blower and paraffin: After 3 minutes the tibia showed with its outermost layer being calcined already. After 10 minutes carbonisation of the facial soft tissues had proceeded to a stage making the body unrecognizable. After 20 minutes shin and calf bone were carbonised sufficiently ''to break easily''. No statements were made about the temperatures.

Based on references in literature Madea [3] arrived at the conclusion in a case to be investigated by him that the fire must have continued for about 20 minutes at a temperature of more than 700°C to reach the degree of destruction found on a body (complete charring of the scalp and the soft tissues of the face, neck and thorax; abdominal cavity showing with the intestine protruding; carbonisation of the extensor sides of both legs with exposure of the partly charred thigh muscles, knee joints and shin bone margins).

A case from forensic practice, in which both the duration of the fire and the temperature were known, is reported by Richards [5]: In a burning flat the body of a man in his fifties was found. It showed deep charring of the muscles with the bones of one arm and the shins showing. The bony structures of the chest and face were not yet exposed. In view of the general circumstances it could be assumed that the fire could not have been going on for more than 10–12 minutes and temperature had not risen beyond 625°C. Richards stated that in the case reported by him the findings were attributable not so much to exposure to a general radiated heat, but more to the impact of a localised fire.

As to the time necessary to largely destroy a human body by fire opinions differ:

- On the basis of his studies Westenhoeffer [1] concluded ''that a constant fire of several hours is entirely sufficient to destroy the bones to an extent that they crumble easily either spontaneously or when touched without the necessary care''.
- Von Hofmann and Haberda [2] stated that in a big oven heated by wood the soft tissues of individual parts of an adult body are in fact burned after one hour, but that the calcined bones are still intact.
- Klein [10] reported that only 1 kg of calcined bone remains were found of a body in the crematorium after 1 hour at temperatures around 1000°C; the same statement was also made by Madea [3].
- According to Prokop [13] bodies are burned in the crematorium at temperatures ranging from 800°C to 1200°C in 45 to 120 minutes depending on size and water contents, leaving only ashes weighing 1–3 kg.

- In contrast to this DiMaio [14] stated that it takes 1.5–2.5 hours to completely cremate a human body at temperatures around 1000°C.
- Spitz [9] reported that in a gas-fuelled cremation oven it takes at least 1–1.5 hours to cremate an adult of average constitution at a temperature of about 800°C.

It is largely agreed that it is hardly possible to destroy a body completely, for example to dispose of the victim of a crime [2,8–10,14,15]. Even severely burned bone remains sometimes offer diagnostic possibilities with regard to sex, age, individual marks and previous injuries [15–20].

The temperatures reached in cremation ovens are similar to those reached in house fires [3,5,9], although due to the fire-fighting operations these normally do not last long enough to consume a human body entirely [5,9,14]. The situation is similar in car fires [21], although temperatures may be higher in such incidents depending on the amount of fuel in the tank, the size of the tank and the type of the car [22].

However, it has to be taken into account that conditions in a cremation oven remain nearly constant during the whole process, whereas in house and car fires the temperature curve shows several phases [5,22]. Although at the beginning of cremation the body is protected from the fire by the coffin, this effect lasts only for a few minutes and can be neglected as against the total time of cremation. As the body is placed on a firestone grid, air and flames can reach it from all sides. Bodies from house or room fires, however, often show only minor damage on the side lying against the floor, as this could not be reached by the flames.

In spite of the above differences it seems justified with the necessary reservation to apply the observations made during cremations to forensically relevant effects of fires. But an estimation of the duration of a fire should not be made before the circumstances of the fire and its effect on the human body have been investigated as thoroughly as possible.

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