Recognition of Atypical Burn Patterns and Pre-cremation Blunt Force Trauma Observed on Human Remains in Two Forensic Cases in the United States

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Abstract

The normal burn pattern of bone color in humans described and illustrated by Symes and colleagues from unintentional fires was compared to the burn patterns seen in two forensic cases from Texas and North Carolina that involved the intentional burning of two victims. Heat altered bone exhibits a range of colors (e.g. white, blue-grey, black, and yellow) from the highest to the lowest exposure of heat. In the Texas case, atypical burn patterns were evinced by an asymmetrical burn pattern on the skull and lower body as well as by the predominantly calcined upper body with a charred lower body. The thermal pattern seen on the body of the North Carolina victim was consistent with a longer heat exposure to the trunk and left side of the body. In both cases, thermal damage did not obscure per mortem blunt force trauma. The atypical burn patterns were diagnostic of intentional fires and contributed to the reconstruction of the events of the crime.

Keywords: Forensic anthropology; Thermal trauma; Burn color pattern; Atypical burn pattern; Blunt force trauma

Introduction

In the forensic analysis of contemporary burned human skeletal remains anthropologists use a variety of analytical techniques to extract information from bones and teeth to aid in the reconstruction of the events surrounding the crime. Some of the techniques used include gross and microscopic examination [1-22] as well as examination of physical properties such as the total weight of cremains [23-31] and chemical analyses of the organic and inorganic elements of cremated remains and other trace elements found in burned bone and teeth [32]. Some analytical chemistry techniques include isotopic composition of bone [33,34], x-ray diffraction [27], and inductively coupled plasma optical emission spectroscopy (ICP-OES) [35].

Gross examination of burned bone and teeth may include: bone and teeth color variations associated with thermal exposure [5-7,9,10,14,18,20,21,23], distortion of burned bone and teeth through shrinkage and warping [8,13,17,19] and fracture patterns [2-4,12,16,18,23,36-38]. Microscopic examination and analysis involves bone histology and the examination of fracture margins to aid in the differentiation of taphonomic effects of thermal alteration from perimortem trauma [1,13,19,39,40].

Symes and colleagues [23] suggest that under normal circumstances when a body is totally engulfed in fire, "bodies will burn in a uniform, recognizable pattern if all external variables are similar" [23] producing a normal burn pattern. The normal burn pattern of a human body is based on three conditions:

1) That the surfaces of the body are equally exposed to the fire,

2) That at the time of heat exposure the body is fleshed with minimal progress in decomposition and

3) The body is in a position that will allow it to contract into the pugilistic pose.

As a result of the contraction of the body into the pugilistic pose, certain areas of the body (and underlying bone) are shielded from heat exposure by the body's soft tissue, while other areas experience greater heat exposure. Therefore, the underlying bone will display a recognizable color pattern that coincides with the amount or duration and intensity of heat exposure. The color pattern is described in Table 1.

In crime scene cases involving burned human remains, bodies may not meet the three conditions mentioned above that result in a normal burn pattern; that is, body surfaces may not be uniformly exposed to heat, the body may not be fleshed and the body may not be able to contract into the pugilistic pose. Thus, when a body does not meet these three conditions a normal burn pattern on bone would not be observed. In the two forensic cases presented, heat exposure to human bodies was a component of both crime scenes with neither case exhibiting a normal burn pattern. The atypical burn patterns observed in these cases with evidence of perimortem trauma on the skeleton were used to aid in recreating the circumstances of the crime and assisted in determining the cause of death by the medical examiner.

Methods

Here we present two forensic anthropology case studies involving the analysis and documentation of partially cremated human remains. One case occurred in Texas, USA and was analyzed by the first and second authors and the other case occurred in North Carolina, USA and was analyzed by the last author. Analysis of the remains included

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Exposure	Bone Color	Bone Condition
Least	Natural bone color (yellow)	Unburned
	Brown	Hemoglobin and/or soil discoloration
	Black	Charred/carbonized
	Blue-grey	Pyrolized
Most	White	Calcined

Table 1. Heat altered bone exhibits a range of colors from the lowest to the highest exposure of heat.

gross and microscopic examination. Gross observation included the examination of color alterations, distortion through shrinkage and fracture patterns of bone and teeth. The fracture margins were also microscopically examined in order to more easily distinguish between fractures due to heat alteration and fractures due to perimortem trauma [18]. Once the analysis was completed, the burn patterns exhibited in the two forensic cases were compared to the normal burn pattern described by Symes and colleagues [23]. Our comparison is illustrated by figures three, four, and six.

Results

Texas case

In April, 2010, at the home of the perpetrator who was a drug acquaintance of the female victim, the female was struck multiple times in the head with a blunt object until she became unconscious and her throat was slit. She was wrapped in a tarp placed in a 90-gallon sealed plastic residential garbage can and placed in the perpetrator's back yard in a shaded area for approximately three weeks. After a three week period, the garbage can was taken to a secluded area of southeast Texas where the body and garbage can were doused with an accelerant and set on fire. In May, 2010, the police were notified of a homicide by an eye witness and the police located the predominantly cremated remains of a female in the secluded area. Because of the extent of fire damage to surrounding brush and trees, arson experts from the Montgomery County Sheriff's Office concluded that the garbage can had been fully engulfed by fire. The only remnants of the fire were the melted bottom of the garbage can, two metal support bars of the can, rivets from the tarp and the predominantly cremated remains of the female (Figure 1).

Prior to the fire, the female had been decomposing in the garbage can in a tightly flexed position (Figure 2) for approximately three weeks. Based on the burn pattern observed on the skeletal remains and the position of the body on the ground prior to recovery, the body appeared to have been placed in the can with the buttocks at the bottom of the can and the head at the top of the can. The average high and low daily temperatures of 26°C and 16°C, respectively, would have allowed the body to reach an advanced stage of decomposition. Because of the advanced state of decomposition of the body, the body would not have contracted into a pugilistic position upon burning as conditions two and three were not met.

As expected, the normal burn pattern was not displayed but rather an atypical burn pattern (Figures 3 and 4). The Texas case displays not only an atypical burn pattern compared to the normal pattern but also an asymmetrical pattern between left and right sides of the skull. The first to burn evidenced by calcined bone was the right side of the facial bones including portions of the internal eye orbit, the complete zygomatic bone, the majority of the maxilla and a portion of the mandibular body that under normal circumstances would have burned last. On the left side of the cranium only a small section of the left orbital margin and a small portion of the maxilla were calcined. The

frontal and parietal bones were predominantly uniformly charred with delamination or splitting of the ectocranial surface from the underlying diploë. Delamination of bone is often observed in thermal damage involving the skull [2] and fractures associated with delamination are common and recognizable. No area of the frontal or parietal bones displayed calcined bone. The right side of the face demonstrates that the bone was exposed to heat for a longer period of time or exposed to a higher temperature than the left side. The asymmetry and unusual burn pattern can be attributed to the degree of decomposition and the body's position in the garbage can.

When comparing the right lateral views of the skull, two distinct patterns are observed (Figure 4). Under normal circumstances the first areas to burn would include the lateral portion of the zygoma, the zygomatic process of the temporal bone, the mandibular condyle and a superior portion of the parietals near the sagittal suture. The last areas to burn would be the majority of the lateral parietal, temporal and occipital bones, the ectocranial surface of the sphenoid and a portion of the lateral posterior maxilla bone.

However, the atypical burn pattern shows that the occipital bone was the first to burn as well as the right temporal bone, which coincides with the similar calcined pattern seen on the right facial bones indicating that the right side of the cranium was exposed to heat for longer than the left side. In contrast to the normal burn pattern seen on the superior lateral side of the skull, the majority of the frontal and parietal bones are uniformly charred with no calcined bone present.

The left side of the skull was uniformly charred with the exception of an area extending from the inferior parietal to the temporal bone that had perimortem trauma. The burn pattern in this region ranged from unburned to calcined (Figure 5).

The calcined occipital was exposed to heat for longer than other skull bones. This may have been due to the position of the head in the garbage can (i.e. the anterior cranium tightly tucked toward the knees, the degree of decomposition and/or the accelerant poured into the can) (Figure 2).

If the body had been in the pugilistic pose the first areas to burn would be those with minimal tissue shielding (Figure 6), which are the lateral portions of the proximal and distal humerus, the acromion process of the scapula, the sternum and sternal rib ends, the dorsal surface of the hands with the exception of the distal phalanges, portions of the iliac crest, the lateral portions of the proximal femur, the knee including the anterior distal femur and proximal tibia and fibula, the anterior crest of the tibia, the medial malleolus of the tibia, the posterior portion of the calcaneus and the distal and intermediate foot phalanges. The last areas to burn include the clavicles, the rib shafts, medial portions of the humerus and scapular body, vertebral bodies, the pelvic inlet, the iliac blade, the mid-shaft of the femur and posterior mid-shaft of the tibia.

The burn pattern on the anterior surface of the postcranial skeleton did not conform to the pattern associated with tissue shielding. The upper body was predominantly calcined, which included the right humerus from the proximal to the distal end and the left humerus extending past mid-shaft. The elbow was the only area charred in contrast to what would be observed in a normal burn pattern where the elbow region is pyrolized to calcined. Most of the ribs from the rib heads to the sternal ends were calcined as well as the vertebral bodies from the cervical to the lower thoracic vertebrae.

Most of the lower body displayed a pattern according to the

Figure 1: The Texas crime scene. The top of the photo (rectangular outline) shows the bottom of the garbage can and the two metal support bars. The center of the photo shows the predominantly calcined upper body (right side of photo indicated by circular outline) and the lower body (left side of photo indicated by the irregular outline).

Figure 2. The assumed position of the body in the garbage can. Drawing by Angela Rippley.

normal color distribution apart from the right and left legs. The right leg was largely charred, while the left leg was charred with no evidence of burning at the mid-shaft of the femur to the patella along with a pyrolized left tibia.

Pre-Cremation Trauma

In addition to the atypical burn pattern of the skull, evidence of perimortem blunt force trauma was observed on the left side of the skull evinced by concentric and radiating fractures. There was also a triangular-shaped unburned bone fragment and a patterned

defect, consistent with a possible tool mark (Figure 5). The tool mark was located on the left parietal bone of the skull near the coronal and squamous sutures approximately 15 mm anterior to the unburned bone fragment. There were multiple pre-existing radiating fractures on the skull evinced by "blunted margins" and the extension of these fracture lines into unburned bone [2]. Since the bone associated with these fractures had remained charred with minimal calcination, the fracture lines were clearly visible and not yet deformed, which often occurs during the calcination process [2]. Some fractures extended from the tool mark, while others appear to have originated from other possible impact areas, but due to missing bone, no definitive point of impact could be determined. The fracture lines created a triangular-shaped bone fragment on the parietal that was unburned. The triangular piece of bone measured approximately 23 mm on each side. With the exception of the postero inferior aspect of the bone no surfaces including edges were burned. The distinct burn pattern seen on the left side of the skull appears to indicate that at some point prior to heat exposure the bone fragment created by the fractures was displaced from its original position and was exposed differentially to heat. Bone displacement was most likely due to the position of the head against the garbage can and the advanced stage of decomposition of the body at the time of transport to the burn scene.

North carolina case

The completely skeletonized and partially cremated remains of a female were found on July 25, 2012 by work crews in a wooded area near a tree line behind a medical building in Cumberland County, North Carolina. A tree next to the body exhibited a vertical charred area of bark with a narrow vertical gray area. Some of her elements had been scattered and showed varying levels of thermal modification. However, the pelvic area with articulated femora was located at the base of the tree and the vertebral column had collapsed to one side of the tree or onto the left side of the body. In addition, a red colored plastic cap, consistent with the lid of a lighter fuel bottle, was recovered from the ground alongside the tree.

The individual had been reported missing at the end of March, 2012. The average daily temperature between March and July was 21.9ºC with an average precipitation of 10.15 cm.

In this case, an atypical burn pattern was displayed that suggests that the body was not completely engulfed in flames, nor was the body exposed to the heat for a prolonged period of time. The pattern of thermal damage was consistent with a longer heat exposure to the trunk and left side of the body, which was also consistent with the pattern observed on the tree trunk (Figure 7).

The burn pattern on the left occipital and mastoid process evidenced by charring, gray coloration and heat line (Figures 3 and 4) was consistent with the head having been canted to the left leaning on the burning tree trunk. The inferior border of the mandible exhibits charring with a heat line along the chin region. Under normal thermal conditions the chin region is minimally exposed to heat. The burn pattern of the skull deviates significantly from the normal burn pattern.

The bones of the left arm and shoulder also had more and longer exposure than the right arm. The vertebral column showed charring on the left side with charring of the pelvic region, which was consistent with the body having been leaning against the tree. The legs showed minimal thermal damage with only the knees having been affected suggesting the decedent had the knees flexed to the left side. The burn pattern displayed on the tree trunk coincides with the pattern observed

Figure 3. Comparison of the normal burn pattern of the skull (anterior view) with the two atypical burn patterns seen in the Texas and North Carolina forensic cases. Based on the anatomical structures of the body and the physiological changes that occur during excessive heat exposure some areas of bone will burn first while others will burn last.
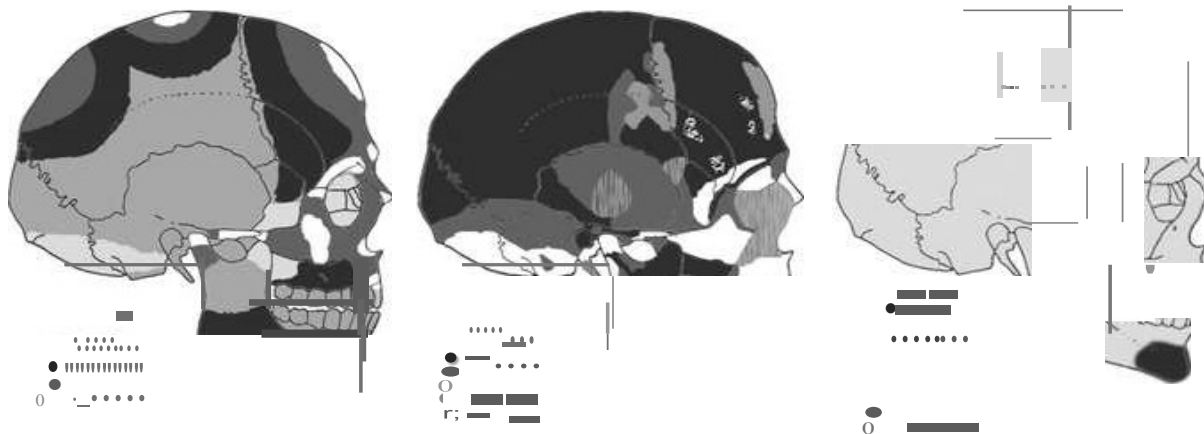

Figure 4. Comparison of the normal burn pattern of the skull (right lateral view) with the two atypical burn patterns seen in the Texas and North Carolina forensic cases.

on the remains, showing extensive charring vertically along the trunk and to the left side with a calcined line where the vertebral column was in contact with the tree (Figure 6).

In addition to the atypical burn pattern, perimortem trauma was evident on the left ulna and radius, which were consistent with Parry or Nightstick fractures (Figure 8). The cross-section of the ulna and radius were   examined under a microscope and showed a uniform pattern of the fracture spanning the burned and unburned portions of bone, which is associated with wet bone fracture [2,23].

Discussion

Even though the burn pattern in both cases presented was quite different from a normal burn pattern for most of the skeleton, the pelvic girdle specifically around the pelvic inlet (with the exception of the inferior portion of the sacrum, which was calcined in the Texas case and charred in the North Carolina case) was similar to the normal burn pattern. Because soft tissue covers the skeleton with varying degrees of thickness, heat will take longer to affect some bones such as the pelvic girdle compared to other areas. In extensive thermal exposure the pelvic girdle often shows evidence of minimal to no burning due to the larger tissue mass. There are two possible explanations as to why the pelvic girdle had similar burn patterns even though the circumstances of the burning were not "typical". Firstly, in the Texas case it is probable that the position of the body in the garbage can aided in the protection of the pelvic girdle. In a tightly flexed position the anterior portion of the lower abdomen would have been adjacent to the upper thighs producing a thick tissue shielding for that area. Secondly, even if tissue had sloughed off as a result of decomposition the tissue would have accumulated at the bottom of the garbage can surrounding the pelvic girdle. The fat accumulated at the bottom of the can may have acted as an accelerant but the amount of decomposition tissue and fluids most likely would have prevented heat alteration.

In the case from North Carolina, the body was in a seated position with the legs flexed and the knees bent to the left side, the lower abdomen and pelvis would have been partially shielded from direct heat. Figures three and four illustrate the differences in bone color between the normal (based on Symes and colleagues' illustrations, [23]) and atypical burn patterns for the Texas and North Carolina cases.

The two cases presented here confirm that if the circumstances

Figure 5: The left lateral view of the skull from the Texas case. Note the perimortem trauma evinced by fractures extending along the parietal bone and a toolmark (shown in the circular outline). Approximately 15mm posterior to the toolmark was an unburned triangular-shaped bone fragment. This would indicate that this piece of bone may have dislodged from its original position prior to the skull being exposed to the heat.
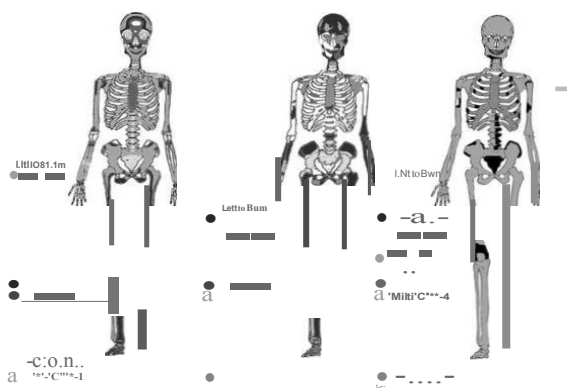

Figure 6. Comparison of the normal burn pattern of the anterior skeleton with the two atypical burn patterns seen in the Texas and North Carolina forensic cases.

Figure 7. The left side of the body was more exposed to thermal trauma. The diagram depicts the probable position of the body based on the burn pattern on the bones and tree trunk.

Figure 8. a. Parry or nightstick fracture of the ulna and radius, b. Cross-section of the distal radius showing consistent fracture pattern spanning the burned and unburned areas (arrows), c. Cross-section of the distal ulna showing consistent fracture pattern spanning the burned and unburned areas (arrows).

under which a body is burned are not normal (i.e. have not met the three conditions mentioned previously), the soft tissue and underlying bone will not burn in a uniform pattern and may indicate suspicious circumstances that would warrant further investigation. While the crime scenes in these two cases would suggest that the expected burn pattern would be atypical because only the first condition (e.g. fully engulfed) was met for the Texas case and only the second condition (e.g. fleshed body) was met for the North Carolina case, the burn pattern each body would exhibit was unknown. An atypical burn pattern was seen on both the cranial and postcranial skeleton for both cases. In the Texas case, the normal burn pattern was not seen due to the catabolism of tissue that occurred during the three weeks the body was decomposing in the garbage can preventing normal contraction of muscles and tissue shielding, the perimortem blunt force trauma to the skull associated with radiating fractures and bone fragments, the position of the body in the garbage can and the accelerant poured on the body and the garbage can. In the North Carolina case, the normal burn pattern was not observed due to the body not being in a fully extended position, but sitting with the pelvic and vertebral column resting on the tree trunk with accelerant decanted on the left side of the tree and body, which prevented normal muscle contraction into the pugilistic pose.

A burn pattern observed on a skeleton can indicate a suspicious death requiring further investigation. A burn pattern is useful for revealing direct and indirect clues. For example, direct clues include whether the bone was green or dry when burned, whether the bone displayed perimortem trauma and whether the bone was burned in a uniform manner. Indirect clues can give leads to investigators to aid in searching for and collecting additional evidence. For example, the tool mark in the Texas case led investigators to interrogate the perpetrator

concerning a class of object used on the victim and led investigators to the home to look for a type of hammer. In the Texas case, the atypical burn pattern also contributed to reconstructing the events of the crime, which corroborated the perpetrator's post-plea confession.

Many analytical techniques are used in the assessment of thermal destruction of bone and teeth. In the present cases, visual observations of burn color pattern on bone depicted in the figures were particularly helpful in recreating circumstances of the crime and aided in assessing the cause of death.

Acknowledgements

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