SKELETAL TRAUMA ANALYSIS
Case Studies in Context

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CHAPTER 7
Shot and beaten to death?
Suspected projectile and blunt force trauma in a case involving an extended period of postmortem water immersion

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Introduction

One of the key aspects of skeletal trauma analysis in a forensic context is determining when the traumatic event occurred relative to the moment of death, thereby identifying perimortem lesions that can be related to the cause and circumstances of death (Saur, 1998; Moraitis and Spiliopoulou, 2006; Symes et al., 2012). While the forensic pathologist defines the term perimortem as the process of death, from the onset of injury and/or disease to the cessation of somatic life, in forensic anthropology, the peri- and postmortem periods reflect the progress in tissue decomposition and changes in compositional characteristics of bone, and how those changes influence the response of bone tissue to external mechanical stress (Symes et al., 2012). Thus, the distinction between peri- and postmortem trauma depends not on whether the lesions can be said to have occurred at the time or about the time of death, but instead relies on the differences between bone that has an intact organic matrix (“green or fresh bone”) and bone that has lost at least part of that organic matrix to decomposition (“dry bone”) (Loe, 2009). Due to varying circumstances in decomposition rates, the time necessary for bone to become dry and lose “fresh bone” characteristics can extend for an indefinite period of time (Symes et al., 2012). As a consequence,
determining whether a specific lesion was produced when the bone was “fresh” may not necessarily answer the question of whether that lesion occurred at or around the time of death. Potentially, this can result in a misunderstanding between the forensic anthropologist and the forensic pathologist.

The distinction between fresh and dry bone fractures is usually based on the analysis of a variety of morphological features of the bone (Ubelaker and Adams, 1995; Galloway et al., 1999; Moraitis and Spiliopoulou, 2006; Wieberg and Wescott, 2008), which are strongly dictated by its condition prior to the fracture being produced. After death, the loss of moisture and organic material in bone affects its ability to resist stress, and so, fresh or “wet” and dry (decomposed) bone show different fracture morphologies (Symes et al., 2012). When subjected to a mechanical force, fresh bone, which is significantly more pliable and has more tensile strength than dried bone (Saur, 1998), will usually pass through an elastic and plastic phase prior to failure (Symes et al., 2012), and will tend to fail along a spiral or helical path and leave a fracture surface that is smooth and at an acute or obtuse angle to the bone’s cortical surface (Outram, 1998). Dried or unfresh bone may resist stress to a higher level, but failure occurs immediately at the end of the elastic phase or the beginning of the plastic phase (Symes et al., 2012). Thus, dry bone tends to fracture in straight lines, with the fracture surface at right angles to the bone’s cortical surface and rougher as a result of micro-cracks (Outram, 1998) and is more likely to shatter into small regular fragments (Saur, 1998).

As taphonomic factors can have such a significant impact on bone decomposition (Ubelaker, 2006; Jaggers and Rogers, 2009), the rate at which bone loses organic and moisture content and becomes dry depends to a great extent on the postmortem environment (Saur, 1998). This means that the length of time required for bone to change its response to mechanical forces after death varies greatly depending upon the conditions to which bones are subjected (Moraitis and Spiliopoulou, 2006; Karr and Outram, 2012). This is perhaps most significant when decomposition occurs in aqueous environments. While it is generally assumed that decomposition in an aquatic environment occurs at a rate roughly half of that of decomposition occurring in sub-areal or surface terrestrial environments (Rodriguez, 2006), the current literature actually shows very scarce and conflicting results on how environmental water and humidity actually affects bone decomposition (Jaggers and Rogers, 2009). Decomposition has been described as accelerating or retarding depending on a number of independent factors, including
water’s chemical characteristics (Gill-King, 2006), as well as human bodily factors, such as body weight and presence of trauma (Ayers, 2010). The lack of information about the effects of an aqueous decomposition environment on the loss or preservation of moisture and organic material in bone is key to the understanding of how bone can react to mechanical forces in the postmortem period when exposed to these environments. In practice, forensic anthropologists rely on thoughtful observation and consideration of taphonomic processes involved in order to accurately interpret skeletal trauma (Ubelaker and Adams, 1995; Moraitis and Spiliopoulou, 2006). Without a proper knowledge of the postmortem environment where the remains were found and its potential effects, interpretations about the timing of skeletal trauma can be extremely challenging.

Exactly how the issues associated with distinguishing a fresh from a dry fracture convert into difficulties in determining whether a specific skeletal injury is the cause or contributing cause of death is often not known. This chapter describes a case of a violent death involving human remains in an advanced state of decomposition, where it appeared as if the victim had been shot and beaten to death. The aquatic decomposition environment and the circumstances in which the remains were initially found combined to create a situation where lesions produced in the postmortem period could have been mistaken for trauma leading or contributing to the cause of death, thus illustrating how these difficulties are translated into a real forensic case.

Case description

In February 2011, a farmer working on his property in a rural area of northern Portugal, contacted the police regarding human remains he had found while clearing a pond used to collect rainwater for use at the farm. The farmer claimed to have discovered a human cranium while clearing the pond of vegetation overgrowth. Police authorities visited the site to investigate the claim and found a set of remains in an advanced state of decomposition, partly immersed and covered by vegetation. The remains were still clothed, and only the cranium and the bones of the left forearm were visible above the pond’s surface. The cranium and mandible were disarticulated, and the teeth had also fallen from their alveoli. Although partially buried in mud and covered with vegetation, the body appeared to be lying on its right side. The police officers on site proceeded to recover
the remains with the aid of volunteers from the local fire brigade, as forensic recovery experts were not called to the scene. Once the remains were retrieved, the investigating officers immediately noted several cranial lesions suggestive of blunt force trauma. The remains were sent to the Forensic Pathology Department at the North Branch of the National Institute of Legal Medicine and Forensic Sciences in Porto, Portugal, for examination. Although the remains were admitted to determine identification and investigate the cause and circumstances of death, no information or photos were provided by the police about the scene where the remains were found or the recovery process prior to the postmortem examination.

During the postmortem examination, extensive saponification of soft tissues was observed. Only the cranium and the left forearm and hand were completely skeletonized. The remains were still fully clothed in heavy winter garments (Figure 7.1). Prior to maceration, whole-body radiographs were taken, which showed evidence of multiple pellets in the thorax, cranium, and upper limbs (Figure 7.2). After maceration, a complete inventory of the remains revealed an almost complete skeleton (Figure 7.3). Police investigation resulted in a potential identification, and the remains were promptly identified genetically. A subsequent detailed analysis of the skeletal trauma was performed by a forensic anthropologist and a forensic pathologist.

Figure 7.1 First examination of the remains, illustrating the state of decomposition of the body.
Figure 7.2 One of the radiographs taken, illustrating multiple lead pellets identified in the torso region.

Figure 7.3 Overview of the remains after defleshing and maceration, laid out in approximate anatomical position (composite photo).

**Trauma analysis**

During the examination of the remains, the following skeletal lesions were identified:

- Two cranial defects in the left parietal.
- Three circular lesions in the facial skeleton.
- Fracture of the body and acromion of the left scapula.
• Fracture of the base of the superior articular facet/transverse process of the first thoracic vertebra.
• Four circular lesions in the sternum.
• Two circular lesions in the third right rib.
• Fractures of the second, third, fourth, and sixth left ribs.
• Comminuted defect in the fifth left metacarpal.

The parietal defects refer to two depressed fractures shaped approximately as a triangle (Figure 7.4). The most anterior defect (C1) is slightly larger and shows several associated concentric fractures around the margins of the lesion. A vertical fracture line extends from this lesion to the spheno-temporal suture at the base of the cranium and traverses the external auditory canal on the left side. The other defect (C2) is located 35 mm posterior to the anterior defect and shows only two concentric fractures around the edges of the injury. Plastic deformation of bone can be seen around these injuries. A vertical fracture line also extends from this second lesion towards the base of the cranium, but it is horizontally deflected after 27 mm in length and terminates in the vertical fracture line of the first defect (Figure 7.5). This fracture line is more regular, stepped, and at right angles to the bone’s cortical surface when compared with

Figure 7.4 Detail of the two parietal depressed fractures shaped approximately as a triangle. C1 is the most anterior and C2 the most posterior.
Figure 7.5 Cranial lateral view, illustrating the position of the cranial fractures C1 and C2 and the deflected horizontal fracture line (see text for more details).

The other fractures. The color of the cortical bone in the margins of all fractures is similar to that of the bone surface.

The remaining cranial injuries refer to two small circular lesions and a circular depressed fracture. One of the circular holes is 3.2 mm in diameter and is located in the right anterior maxilla just right of the infra-orbital foramen (Figure 7.6). The other circular hole is larger and more irregular, approximately 8.1 mm in diameter, and is located in the posterior right maxilla by the right sphenoid-maxillary suture. There are no concentric or radiating fractures associated with these injuries. The circular depressed fracture is located in the right frontal bone, approximately halfway between the frontal eminence and the midline. This lesion is 4.6 mm in diameter and shows metallic residue along its margins (Figure 7.7). There are also no concentric or radiating fractures leaving this injury.

The two lesions of the left scapula include a complete fracture of the acromion process and an incomplete fracture of the body that extends from the superior third of the medial border to the supraspinous fossa. These fractures show an irregular outline, but their margins are lightly colored when compared with the bone surface. The first thoracic vertebra shows two incomplete fractures of the left and right pedicles/superior
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Figure 7.6 Anterior cranial view, illustrating the facial circular lesion located in the right anterior maxilla, just right of the infra-orbital foramen. The inset provides a close-up detail of the lesion.

Figure 7.7 Circular depressed fracture located in the right frontal bone, approximately halfway between the frontal eminence and the midline. Note metallic residue around the margins of the lesion.
Figure 7.8 Anterior view of the sternum illustrating the two circular lesions located on the left margin of the sternum body by the third rib notch (S1) and towards the midline and between the notches for the fourth and fifth ribs (S2). The insets provide a close-up detail of the lesions.

articulart facets. In an inferior view, these fractures develop into an incomplete triangle with a posterior base and an anterior apex.

In the body of the sternum, two anterior and two posterior circular lesions were identified. The anterior lesions are approximately 2.5 mm in diameter and 44 mm apart on top of one another (Figure 7.8). The superior hole (S1) is located on the left margin of the sternum body by
Figure 7.9 Posterior view of the sternum illustrating the two circular lesions located on the left margin of the sternum body by the third rib notch (S3) and towards the midline and between the notches for the fourth and fifth ribs (S4), opposite of S1 and S2, respectively (see Figure 7.8). The insets provide a close-up detail of the lesions.

There are no concentric or radiating fractures associated. The posterior lesions are opposite to the anterior ones described above and are also circular, albeit more irregular and larger (Figure 7.9). The superior defect is 6.6 mm (S3) and the inferior defect is 3.6 mm (S4) in diameter, and
in both lesions a smaller circular defect can be seen inside each of the holes, particularly in the inferior defect (Figure 7.9). There are also no concentric or radiating fractures associated with these lesions.

Additional circular lesions were detected in the sternal end of the third right rib. The ventral defect is 3.5 mm in diameter (Figure 7.10) and is opposite of the visceral defect, which is more irregular and 4.3 mm in diameter (Figure 7.11). There are three radiating fractures extending from the visceral injury, with displacement of a fragment of cortical bone. The remaining lesions identified in the rib cage refer to oblique or transverse complete fractures of the posterior third of the shaft in ribs 2–6, on the left side (Figure 7.12). All fractures are located in the area immediately anterior to the tubercle, except in the second rib, which is more anteriorly located. The second rib is also the only one showing a transverse fracture, whereas all others showed an oblique fracture. From a superior view, the oblique fractures develop into an incomplete triangle, with a posterior (dorsal) base and an anterior (visceral) apex. In the fifth rib, this incomplete triangle turns into a triangular fragment of bone that broke away, as is typical of butterfly fractures.

The last injury was detected on the left fifth metacarpus and it refers to a comminuted fracture on the dorso-lateral aspect of the distal epiphysis,
Figure 7.11  Visceral view of the third right rib, illustrating the circular lesion located at the sternal end, opposite to the lesion illustrated in Figure 7.10. Note radiating fractures.

Figure 7.12  Superior (cranial) view of left ribs 1–7, illustrating transverse (second rib) or oblique (third to sixth ribs) complete fractures of the posterior third of the shaft.
immediately behind the head (Figure 7.13). There are five radiating fractures extending to the superior and inferior side, displacing bone fragments. The superior fractures extend halfway across the diaphysis and the inferior fractures stop at the articular eminences. There is a sixth fracture affecting the volar surface, which is not radiating from the comminuted defect.

Discussion and conclusions

The lesions described above seem consistent with blunt force trauma to the head and thorax, and with gunshot trauma to the head, thorax, and hand, but the police account of the death scene and circumstances of the recovery after the postmortem examination confirmed early suspicions about the perimortem nature of some of these injuries.

The morphology of the two left parietal fractures is consistent with blunt force trauma inflicted to fresh bone, by an instrument of possible triangular cross-section, acting with significant force on a reduced surface. The fractures in the first thoracic vertebra, and in the posterior arch of the second, third, fourth, fifth, and sixth left ribs also show features
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which are also consistent with blunt force injury inflicted to fresh bone. These fractures, in particular, suggested an impact on the back towards the front, by interpreting the shape and location of the oblique/butterfly fractures produced (Berryman and Symes, 1998; Galloway et al., 1999). The small round defects located in the facial skeleton are compatible with entrance and exit satellite wounds caused by multiple metallic pellets to fresh bone. These wounds are consistent with a distant range shotgun shot, of relative low impact velocity and a trajectory from front to back (DiMaio, 1999). The third cranial lesion suggests that one of the projectiles had a more tangential trajectory relative to the bone surface and ricocheted. In the sternum, the anterior lesions are consistent with entrance wounds and the posterior with exit wounds involving lead pellets with the same trajectory. In the sternum, the outward beveling of the exit lesions is noteworthy, particularly in the inferior defect. The lesion in the third right rib is similar to that of the sternum and is also consistent with similar ballistic trauma. In the distal epiphysis of the fifth metacarpal, the entrance and exit wounds are not recognizable, but the lesion suggests that this is punched out plug (entrance/exit defect) associated with radiating fractures (Smith et al., 2003).

Although features of the ballistic lesions offer little doubt to their etiology, the injuries consistent with blunt force trauma were not as straightforward. Some of these injuries were consistent with a post-mortem timing of production, namely the fractures observed on the left scapula, which showed irregular but clean breaks with clearer colored cortical bone, compared with that of the bone surface (Saur, 1998). Other findings also raised the suspicion that the blunt force injuries to the head might also have been produced after the bone started losing its qualities of fresh or living tissue. Although these lesions showed features consistent with blunt force trauma to fresh bone, such as plastic deformation, depressed fractures with adhering flakes or similarly colored cortical bone and surface (Saur, 1998; Galloway et al., 1999) one of the radiating fractures shows an unusual horizontal deflection and is more regular, stepped, and displays a cleaner break. Perhaps the blunt force injuries that offered less doubt were those of the thoracic vertebra and ribs. These lesions showed similarly colored cortical bone and surface, and typical tension and compression fractures of fresh bone as seen in butterfly fractures (Smith et al., 2003).

Eventually, the lesions indicative of blunt force trauma to the skeleton were excluded from being associated with the time and cause of death as circumstances of the death scene corroborated initial suspicions
about the postmortem nature of these injuries. In fact, as in most cases, information from the death scene proved vital to the interpretation of the findings. According to the police investigators, the farmer was beating down the vegetation with a shovel and a sickle, while he was clearing the pond where the human remains were eventually found. The farmer specifically stated that he used the shovel and sickle to turn and pull the cranium towards him for observation. He also stated that he was certain not only that he had walked over the remains several times, but also that he struck the cranium in several occasions with the shovel and sickle, before the pond was cleared and the remains were visible. The size and shape of the sickle (Figure 7.14), in particular, are compatible with the blunt force injuries detected in the cranium. Consequently, after thoughtful consideration of the postmortem findings and of the police information, all blunt force injuries were considered to originate from the postmortem period. The lesions are considered consistent with the blows from the shovel and sickle, and with the weight-bearing stress caused by the farmer while stepping on the remains.

Once the remains were removed from the death scene, the police officers initiated a search in the pond, having found a broken shotgun with a 12-gauge red color cartridge brand “TILT 2000” already triggered inside,
which was later confirmed as the murder weapon. After the victim’s identification, police investigation narrowed down the murder suspects to a young relative, who was a known criminal and a suspected drug abuser. Under police interrogation, the suspect confessed the murder and stated that he had killed the victim with a shotgun. The suspect denied any other type of physical aggression towards the deceased or the use of any other weapons, including blunt force instruments.

In this case, the careful consideration of the skeletal findings and the honest testimony of the individual who found the remains were essential to establish the cause and circumstances of death, and eliminating blunt force trauma as cause or contributing cause of death. Although these blunt force injuries occurred almost certainly in the postmortem period, they show features typical of fractures being produced in fresh bone. Considering that the victim remained submerged in the pond for a period of approximately 2 years, the constant presence of fresh water in the pond probably created specific conditions that allowed for bone tissue to preserve the physical and chemical properties of fresh bone for a considerable period of time. There is still scarce research being carried out to explore the influence of water immersion on the decomposition and preservation of bone tissue. Although available evidence suggests water in which bodies are totally or partially submerged may accelerate or retard decomposition (Gill-King, 2006), perhaps of major importance is the ability of water in certain circumstances to slow down certain chemical reactions and microbial activity which are vital to the preservation of collagen and bone mineral (Gill-King, 2006; Turner-Walker, 2008).

This chapter illustrates the difficulty faced by the forensic anthropologists in distinguishing perimortem from postmortem lesion on the basis of fresh versus dry bone-type injuries. In this case, several lesions showed typical features of being produced while the bone was still in a fresh state, but where considered postmortem and unrelated to the cause and circumstances of death due to early inconsistencies in the pattern of skeletal trauma and later to police information about the conditions of the death scene. Consideration of the particularities of the postmortem environment and its effects on bone preservation are vital for the interpretation of trauma, even in skeletonized human remains with a significant postmortem interval. In particular, this case cautions against interpretations of skeletal lesions based on the plastic response of bone when the depositional environment favors the preservation of fresh bone characteristics.
Acknowledgments

The authors would like to thank the editors of this volume for their generous invitation to contribute. All images courtesy of the National Institute of Legal Medicine and Forensic Sciences, Portugal.

References


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