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Evaluation of trauma patterns in blast injuries using multiple correspondence analysis

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ABSTRACT

Anthropology features little in published literature about blast injuries. Contributions through case studies and experimental research are beginning to expand our understanding of the effect these injuries have on the human skeleton. This study examines blast injury and gunshot related fractures through multiple correspondence analysis (MCA) with the aim of establishing injury patterns between the two types of trauma. Using a sample of 491 individuals from Bosnia, MCA is employed to identify which body regions differentiate between blast or gunshot related fractures. Cranial fractures were more closely associated with gunshot related cases. Post-cranial fractures were associated with blast-related cases. A differentiation in post-cranial and cranial fractures between gunshot and blast related cases was revealed in the samples. The high prevalence of extremity trauma in blast is similar to previous work, but the smaller amount of cranial blast-related fractures differs from previous studies and from what is found in gunshot-related cases. Differentiation of blast and gunshot wound injuries can be made on the human skeleton and can be used to possibly interpret injury mechanism in large skeletal assemblages as well as single cases.

1. Introduction

Clinical publications are the foundation for knowledge on blast injuries in the human skeleton. In the last ten years, research on blast injuries has primarily targeted the pathogenesis and etiology of traumatic brain injury along with the medical management of musculoskeletal injuries and limb salvage [1–5]. In the anthropological analysis of trauma, examination of blast injury features little in published literature, with most information associated with case studies [6,7] and some experimental research [8].

Medical classification of blast injuries is a four-tiered system that was developed on the basis of blast physics and mechanism of injury [9,10]. Primary blast injury is the result of blast wave overpressure and affects the air or fluid filled organs. Experimental work links primary blast injury with skeletal trauma to the ribs and traumatic amputations [8,11,12]. Secondary blast injury represents injuries caused by the fragmentation of munitions and the impact of these fragments on the human body. This includes fractures, often represented by irregular fracturing of bone with characteristics of ballistic injury [13]. Tertiary blast injury results from the movement and impact of the body against an immovable object. Injuries from the impact of objects into the body are also classified as tertiary. Tertiary injuries can result in blunt force fractures to skeletal elements. Quaternary blast injuries refer to thermal and chemical damage to the body [9].

As a blast is a broad-focused force, injuries are predominantly distributed throughout the body [14]. However, the location of the explosion to a victim does influence fracture variation. Other variables, such as whether the person is an open or enclosed environment can also influence the pattern of trauma [14–17]. For example, terrorist bombing events (occurring in both enclosed and open areas) typically result in a high prevalence of extremity injuries, particularly to the head and lower limbs [18–20]. Contrasting this pattern, suicide bombings have a greater number of soft tissue injuries rather than fractures. This may be due to the inclusion of shrapnel-type materials from improvised sources such as ball bearings, pieces of metal and nails [7]. In general, fractures occur typically in the lower limbs in both terrorism and suicide bombings [14,21–24]. However if both types of bombings occur in

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a confined area (such as a building), the blast overpressure will be reflected back onto the victims and will result in a potentially higher number of primary blast injuries [25,26].

Patterns of injury in gunshot wounds vary from those of blast injuries, and an understanding of the observable fractures patterns is useful for differentiating them [10]. Common areas affected by gunshot wounds are the chest, spine and abdomen and include injuries concurrently seen in only one or two body regions, whereas blast injuries, as mentioned above, are more diffuse across the skeleton [27,28]. Forensic contexts often address questions regarding the distribution and nature of blast-related fractures and their similarities or differences to gunshot related injuries. Both the identification and differentiation of blast and gunshot related fractures has been legally questioned [29] in cases of human rights abuses. To date, baseline data are not available from which to compare blast and gunshot related injuries and to assess whether the certain trauma patterns are consistent with these types of trauma. Therefore, the purpose of this study is to describe blast fracture patterns and to compare, and possibly differentiate, from the gunshot injury fracture patterns in the human skeleton.

2. Materials and methods

The International Commission on Missing Persons in Sarajevo, Bosnia (ICMP) provided pathology reports, anthropology reports, autopsy photographs and site photographs from the analysis of five mass graves from the Glogova, Zeleni Jadar and Lazete excavations. The total sample size was 491 males, aged from 8 to 75 years. Pathologists provided the cause and manner of death of each person based on observed trauma (in both soft and hard tissues) and associated evidence, such as shrapnel embedded in the tissues. Cause of death was determined to be either gunshot wound or blast. Forensic investigators used physical evidence to corroborate the cause and manner of death and demonstrated associated use of rocket-propelled grenades for the blast-related cases [30], also supported by witness statements. Only cases in which a cause of death was determined were included in the sample. Cases with blast related fractures were from an enclosed context. The primary author assessed whether the damage was perimortem or postmortem before comparing the bone injuries to the soft tissue trauma in the pathology reports. This confirmed inclusion in the study based on presence of perimortem blast or gunshot-related fractures, for each individual case. Perimortem damage identification followed guidelines from previously published studies commonly employed in forensic anthropology practice [31–33], and is the differentiation of fractures on wet and dry bone [34,35].

The distinction between perimortem and postmortem fractures used characteristics of the angle, outline and edge of the fractures [36]. Perimortem fractures characteristics were an oblique (eitherobtuse or acute) angle between the fracture surface and bone cortical surface, three types of fracture outline (transverse, curved or v-shaped) and the texture of the fracture margin (smooth, straight margins associated with wet bone fractures). Postmortem characteristics were a right fracture angle, jagged edges to the texture of the fracture as well as color variation of the fracture surface and the internal and external bone surfaces. Cases with extensive post-mortem damage and cases with ambiguous distinctions between fresh and dry bone fractures were excluded from the study.

With selected perimortem fracture cases, the type of trauma was assessed. Forensic pathologists identified morphological characteristics of gunshot wounds such as entrance and exit defects (with or without associated bullet fragments), bullet tracks, fragmentation patterns in bone and the presence of intact or fragmented bullets in the soft tissues. Shrapnel trauma and blast injury was identified by the presence of irregular damage in bone which is not typical of gunshot or blunt force trauma and was associated with shrapnel and sometimes charring [37].

Data compiled from the reports were entered into a Microsoft Excel™ spreadsheet. A dichotomous scoring system (represented by 1 for absent and 2 for present) was used to identify which body regions had perimortem fractures, as detailed in Table 1. The divisions were created so as to specifically focus on an individual bone, or groups of closely related bones in one body region. Each case was classified by type of trauma, either gunshot or blast-related fractures.

Multiple correspondence analysis (MCA) was used within SPSS (19.0). MCA was used to examine sample variance as a measure of similarity or dissimilarity between the perimortem, or wet bone, fracture patterns among the various body regions. The greater the variance between two samples in the study the more dissimilar they are. By selecting the variables that account for the most variance and graphically projecting these onto three axes, observable differences between the patterns of fractures can be visualised.

The sample of cases with gunshot related fractures was much larger than the sample with blast related fractures. Multiple

Table 1
Description of the body region variables, including the bones assigned to each body region.

Body region (variable)	Bones included
Neurocranium	Frontal, parietal, temporal, occipital
Maxillofacial	Maxillae, palatines, vomer, inferior nasal conchae, ethmoid, lacrimals, nasals, zygomatics, sphenoid
Mandible	Mandible
Vertebrae	Hyoid, cervical, thoracic, lumbar, sacral vertebrae and coccyx
Left shoulder girdle	Left clavicle, left scapula
Right shoulder girdle	Right clavicle, right scapula
Left upper arm	Left humerus
Right upper arm	Right humerus
Left forearm	Left radius, left ulna
Right forearm	Right radius, right ulna
Left hand	Left carpals, left metacarpals, left hand phalanges
Right hand	Right carpals, right metacarpals, right hand phalanges
Left ribs	Left ribs and left half of sternum
Right ribs	Right ribs and right half of sternum
Left pelvis	Left pelvis
Right pelvis	Right pelvis
Left femur	Left femur
Right femur	Right femur
Left tibia and fibula	Left tibia and fibula
Right tibia and fibula	Right tibia and fibula
Left foot	Left tarsals, left metatarsals and left foot phalanges
Right foot	Right tarsals, right metatarsals and right foot phalanges