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## Blast injury prevalence in skeletal remains: Are there differences between Bosnian war samples and documented combat-related deaths?

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### ABSTRACT

Court cases at the International Criminal Tribunal for the Former Yugoslavia (ICTY) have seen questions raised about the recognition and causes of blast-related trauma and the relationship to human rights abuses or combat. During trials, defence teams argued that trauma was combat related and prosecutors argued that trauma was related to executions. We compared a sample of 81 cases (males between 18 and 75) from a Bosnian mass grave investigation linked to the Kravica warehouse killings to published combat-related blast injury data from World War One, Vietnam, Northern Ireland, the first Gulf War, Operation Iraqi Freedom and Afghanistan. We also compared blast fracture injuries from Bosnia to blast fracture injuries sustained in bombings of buildings in two non-combat 'civilian' examples; the Oklahoma City and Birmingham pub bombings. A Chi-squared statistic with a Holm-Bonferroni correction assessed differences between prevalence of blast-related fractures in various body regions, where data were comparable. We found statistically significant differences between the Bosnian and combat contexts. We noted differences in the prevalence of head, torso, vertebral area, and limbs trauma, with a general trend for higher levels of more widespread trauma in the Bosnian sample. We noted that the pattern of trauma in the Bosnian cases resembled the pattern from the bombing in buildings civilian contexts. Variation in trauma patterns can be attributed to the influence of protective armour; the context of the environment; and the type of munition and its injuring mechanism. Blast fracture injuries sustained in the Bosnian sample showed patterns consistent with a lack of body armour, blast effects on people standing in enclosed buildings and the use of explosive munitions.

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### 1. Introduction

Court cases at the International Criminal Tribunal for the Former Yugoslavia (ICTY) saw arguments based on the autopsy of skeletal remains. Trauma assessments of skeletal remains can determine the manner and cause of death. During trials at the ICTY, prosecution argued that the cause of death was execution related and defence teams argued that the pattern of trauma seen in these cases was combat-related [1–4]. The latter argument was presented most prominently during the trials of the former Bosnian Serb military leaders Radovan Karadžić, Ratko Mladić, and Zdravko Tolimir for war crimes committed during the 1995 civil war in Bosnia. The defence arguments attributed observed injuries to a confrontation between two armed groups, resulting in combat deaths.

In a previous study, general patterns of gunshot-related trauma and injury were used to indicate forensic differences between remains found in Bosnian mass graves and remains from other combat situations

[5]. A review of literature indicates combat-related injuries are often characterised by the presence of shrapnel and blast-related injuries [5, 6], but assessments are complicated by the lack of standard classification and description of blast-related fractures in the human skeleton. Previously, most of the available information was presented in a medical management context rather than an osteological one [5], however, a number of publications have now detailed the anthropological aspects of the study of blast injury [7–9]. Blast related injuries are classified in four broad categories [10–12]. Primary blast injuries typically affect the air-filled organs, such as the lungs. Secondary blast injuries, the most commonly encountered injuries, are caused by the impact of materials into the body (such as shrapnel). The injuries resemble ballistic injuries, with blunt or ballistic penetration injuries [13–15]. Tertiary injuries are characterised by the movement of the body and its subsequent impact on structures, resulting in blunt injuries [12, 16–18], resembling falls from height or the impact of an object on a bone [19]. Quaternary blast injuries are those which do not fall into the previous categories, such as burns. Injuries of anthropological interest are usually from the secondary and tertiary categories. Using blast-related fractures to discern between combat and human rights abuses requires examination—where possible—of the total body pattern of blast-related fractures

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in a sample of cases and comparing these to previously published studies on combat trauma.

This study examines the prevalence and distribution of blast-related fractures in a sample from documented Bosnian mass graves and compares the pattern to data from published studies of combat injuries spanning modern conflict. We also investigate if there are differences and similarities in the prevalence and distribution of blast-related fractures between civilian and combat-related casualties. Whilst investigators have presented evidence of human rights abuses in international courts, few studies have assessed if the distribution of injuries differs between victims of combat or human rights abuses. Our study is the first anthropological study attempting to address the question and determine if it is possible to differentiate between blast-related fractures from war crimes victims and combat casualties by examining the prevalence of these injuries in known blast-related deaths.

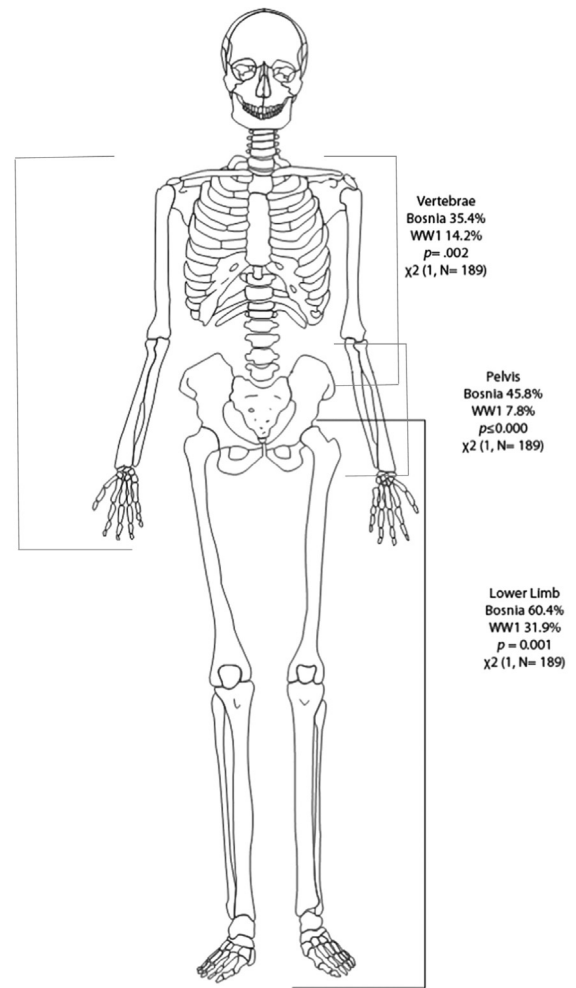
2. Materials and methods

The lead author (MCD) used data collected from autopsy and anthropology reports of known blast-related cases provided held at the International Commission on Missing Persons (ICMP). The ICMP provided ethical approval and the lead author signed a standard research agreement. Additional approval was granted by the ethics committee at the University of Pretoria (Ref: 40/2016). The study compiles data from four mass graves, forensically linked to the Kravica warehouse case [20]. Documented evidence indicates that killings took place inside a building with the use of gunfire and hand grenades. Men were documented as standing closely-packed together in large numbers in the building, then fired upon with automatic weapons and hand grenades from different directions and killed, after which bodies were moved to graves [21,22]. We gathered cause and manner of death data from case records compiled by pathologists and forensic investigators. The sample size was 48 cases with evidence of blast trauma, all of which were documented as males, aged between 8 and 75 years. No recording of individual case numbers or discussion of identifying features were included in this study.

Cases were included if perimortem blast-related fractures were present as recorded in the pathology and anthropology autopsy documentation and photographs. Perimortem trauma was observed in photographs occurring on wet and dry bone [23,24]. Characteristics examined include the angle, outline, and edge of fractures [25]. The features of perimortem or wet bone fractures were an oblique obtuse or acute angle between the fracture and the cortical bone surface, the fracture outline shape (transverse, curved or V-shaped) and whether the fracture margin was smooth and straight as seen in the photographs and described in the reports. Postmortem or dry bone fractures were observed in the autopsy photographs by characteristics such as a right fracture angle, jagged edges to the texture of the fracture and colour variation between the fracture surface and the internal and external bone surfaces were noted. Gunshot trauma was found to be prevalent but this was not the focus of the study and only cases with recognised and documented blast injury was used.

**Table 1**  
Prevalence of trauma and results of  $\chi^2$  (1, N = 189) analysis showing significant differences in the prevalence of blast-related fractures in the vertebrae, upper limbs, pelvis and lower limbs between cases from WW1 and Bosnian mass graves. Statistically significant differences shown in bold.

Body region	p-Value	Prevalence WW1 (N = 141)	Prevalence Bosnia (N = 48)
Upper limb	<b>p ≤ 0.000</b>	22.7%	68.8%
Pelvis	<b>p ≤ 0.000</b>	7.8%	45.8%
Lower limb	<b>p = 0.001</b>	31.9%	60.4%
Vertebrae	<b>p = 0.002</b>	14.2%	35.4%
Torso	p = 0.056	31.9%	47.9%
Head	p = 0.314	41.1%	50.0%



**Fig. 1.** Distribution of areas of the body that are statistically significantly different in prevalence of blast-related fractures between the sample from Bosnia and the sample from WW1.

Comparative data were collected from a range of previously published papers along with primary data from the Canadian World War One (WW1) death registers, available online from Library and Archives Canada. The cases chosen from this source are available at the Library and Archives Canada website (<http://www.bac-lac.gc.ca/eng/discover/mass-digitized-archives/circumstances-death-registers/Pages/circumstances-death-registers.aspx>) and were anonymized by excluding the names and service numbers that are available in the source data. The primary author selected cases with associated trauma from mortar blasts as this explosive munition is similar to the fragmentation-type grenades used in the Bosnian cases [26,27]. The sample included 141 cases, all were male, over the age of 18.

The published combat data used for comparison included conflicts from Vietnam (1955–1975), Northern Ireland (late 1960’s-1998),

**Table 2**  
Prevalence of trauma and results of  $\chi^2$  (1, N = 36,788) analysis showing statistically significant differences in the prevalence of blast-related fractures in: head, neck, and face; thorax and back; upper limb; and lower limb between cases from Vietnam and Bosnian mass graves. Statistically significant differences shown in bold.

Body region	p-Value	Prevalence Vietnam (N = 36,740)	Prevalence Bosnia (N = 48)
Head, neck, and face	<b>p ≤ 0.000</b>	20.6%	50%
Thorax and back	<b>p ≤ 0.000</b>	8.8%	47.9%
Upper limb	<b>p ≤ 0.000</b>	27.2%	68.8%
Lower limb	<b>p = 0.008</b>	40.9%	60.4%

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