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An Analysis of Wound Statistics in Relation to Personal Ballistic Protection

Christopher G. Brady

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ABSTRACT

This report summarises data on gunshot and fragmentation wounds (collectively called "missile wounds") drawn from journal articles available in the public domain. Wound location is discussed with respect to military personal body armour (helmets and protective vests). The data is reviewed according to areas of past conflict (Vietnam, Persian Gulf, Northern Ireland, Lebanon and Croatia). It was found that helmets offered significant protection against fragments. This is important given that fragmentation wounds accounted for up to 90% of all missile injuries. The head should be considered to be a high priority area of protection, given that it received up to 7 times more wounds than would be expected given its size relative the the body. Also, in some conflicts, over 35% of wounds were to the upper-mid chest, supporting the idea that a bullet-resistant strip is needed in this area.

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An Analysis of Wound Statistics in Relation to Personal Ballistic Protection

Executive Summary

This report summarises data on gunshot wounds and fragmentation wounds (collectively called "missile wounds") found in journal articles available in the public domain. The aim is to discuss wound location with respect to military personal body armour (helmets and protective vests) . The data presented here is divided into areas of past conflict (Vietnam, Persian Gulf, Northern Ireland, Lebanon and Croatia).

The majority of deaths on the battlefield are caused by penetrating injuries. The use of body armour may reduce the percentage of lethal penetrating wounds. This data suggests that protective vests and helmets can stop small shrapnel and reduce the impact of large shrapnel but are incapable of preventing injury from high velocity bullets.

There is a need to consider the head as a high priority area of protection. In Vietnam wounds to the head were more likely to be fatal than wounds to any other part of the body. In both Northern Ireland and Lebanon the head was very susceptible to wounding considering its relatively small size, receiving up to 7 times more wounds than would be expected given the size of the head.

Fragmentation wounds accounted for 65-84% of all missile wounds in WW2, 68% in Korea and 50% in Vietnam. However, the combat helmet offers limited protection with almost a third of all wounds to the head struck below the level of the helmet. In Lebanon, that figure was higher, with three quarters of all head shots received in the face. One repeated finding was that helmets offered significant protection against fragmentation

A helmet with increased protection on the front and less on the back would increase protective ability without significantly increasing weight. Despite the fact that the face had a very high hit ratio, protection of the face is difficult. A face visor with significant ballistic protection would be so thick as to present many problems to the user. A brim on the helmet is recommended to reduce injury from missiles coming from above. In some conflicts, over 35% of wounds were to the upper-mid chest, supporting the idea that a bullet-resistant strip is needed in this area.

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Chris Brady completed his BA with honours in Psychology at the Flinders University in 1992. For the next six years he worked as a medical technician at sleep research and clinical laboratories in both Adleiade and Syndey. In October 1998 Chris joined LOD as a Professional Officer in the Human Factors Discipline. Since joining DSTO Chris has been involved in work on night vision goggles, posture, anthropometry and helmet systems. He completed his Masters in Cognitive Science at Adelaide University in 2001.

Contents

1. Introduction

This report summarises data on gunshot wounds and fragmentation wounds, which are here collectively called "missile wounds". All data is collected from journal articles available in the public domain. The aim of this paper is to discuss wound location with respect to military personal body armour, which includes both helmets and protective vests. Where possible, the distinction is made between lethal and non-lethal wounds. The data presented here is divided into areas of past conflict (Vietnam, Persian Gulf, Northern Ireland, Lebanon and Croatia). This division is in part because most of the articles reviewed concentrated on one area of conflict, but the varied nature of war fighting in each region justifies separate reviews. An emphasis is placed on military casualties but mention is made of civilian casualties for comparison.

This paper is written as part of DSTO's effort to support Project Land 132: The Raising of a Full Time Commando Regiment. There are two questions to be answered by this investigation. Firstly, can, and to what extent have helmets and vests provided protection in past conflicts. Secondly, can helmet and vest design be optimised based on data of wound location to achieve maximum protective ability?

The data presented here reflects casualties from 'war roles' activities, and does not deal with specialist Close Quarter Battle (CQB) scenarios. This limitation is due to the lack of data in the public domain on CQB operations.

The majority of deaths on the battlefield are caused by penetrating injuries (Grofit, Kovalski, Leibovici, Shemer, O'Hara & Shapira, 1996). The use of body armour may reduce the percentage of lethal penetrating wounds. This data suggests that Aramid vests and helmets can stop small shrapnel and reduce the impact of large shrapnel but are incapable of preventing injury from high velocity bullets. By their nature, military bullets are high velocity, high energy missiles. Pyper and Graham (1983) note that high velocity bullets have more energy to impart than low velocity or subsonic bullets. High velocity bullets cause damage by the tumbling of the missile and the resulting cavitation of the wound. Such wounds are always infected (Whitlock & Gorman, 1978). Low velocity bullets cause less damage and are often deflected along tissue planes, thus avoiding important internal structures.

Many of the articles cited in this report were intended to inform the medical industry of the nature of the medical effort involved in various military operations. However, some of these data do not include soldiers killed in combat or moribund on admission. Care should therefore be taken not to generalise all of these results to reflect the incidence of injury, only of the incidence of admission. Also, some patients had more than one injury, therefore the patient numbers do not necessarily equal wound numbers, and vice-versa.

2. Vietnam War

Combat during the Vietnam War was characterised by close contact in jungle environments. Many of the wounded were victims of booby traps and short-range rifle fire. Data on wounds suffered by US Army soldiers in Vietnam was collected by a Wound Data and Munitions Effectiveness Team (WDMET) from July 1967 to June 1979. By January 1970, 5563 cases had been recorded. 83% of those wounded survived their wounds, 15% died in action, and 2% died subsequent to the action from their wounds. It should be noted that the Aramid helmet was not introduced until after the Vietnam War. A standard metal helmet was used during the Vietnam War.

A report by Carey, Sacco & Merkler (1982) reviews the data from 99 randomly selected fatal head injuries and 30 randomly selected non-fatal head injuries from the WDMET database. Of the 129 samples, 87% of all wounds occurred whilst on offensive operations, with the remaining 13% on defensive operations. As shown in Table 1 approximately 63% of fatal wounds were caused by bullets, the remainder caused by fragmentation. Half of the fragmentation wounds occurred as a result of booby traps.

*Table 1: Number of head wounds that were fatal and non-fatal according to missile type (Carey et al. 1982) * = 8 of these died of other injuries to the body, not the fragmentation injury*

Type of Missile	Fatal (n = 99)	Non-Fatal (n = 30)
Bullet	63	8
Fragment	36*	22

Some 89% of bullet wounds were caused by a single shot but only 60% of fragment wounds were caused by a single fragment. Of the 129 cases reviewed, 41 injuries (32%) were caused by a missile that struck below the level where a helmet would protect. Data on head protection was only available for 47 of the 99 fatally wounded men. Forty three of these 47 men (91%) were wearing helmets at the time of receiving the injury. In 19 instances the bullet penetrated the helmet before inflicting the fatal wound. In no instance did a fragment penetrate a helmet and cause a fatal wound. This suggests that wearing the standard issue metal helmet offered significant protection against fragments, but only protected against bullets about half of the time.

Gauker, Anderson and Blood (1994) collected wound data from a number of different combat operations as part of a medical resource planning report for the US Army. With respect to Vietnam, an analysis of injury characteristics revealed that 62% of injuries received in Vietnam by US forces were open wounds (as opposed to blunt trauma, sprains or bone fractures, for example). However, these figures do not represent just bullet and fragment wounds, as that data is not available. Also, the analysis showed 14% of all injuries were received to the head.

White (1969) analysed an early version of the WDMET data (data from July until September 1967 only) and produced data on the range of wounding from different kinds of weapons. In summary 50% of all casualties occurred at a range of under nine and a half metres. Fragmentation weapons (mines, booby traps, grenades) inflicted casualties at shorter ranges than did small arms.

Table 2: Percentage of wounds at each location that are fatal by weapon type (White, 1969)

	Head	Thorax	Abdomen	Legs	Arms
Small Arms	70	51	40	5	> 1
Mines/Booby Traps	38	25	14	2	> 1
Grenades	23	16	7	2	> 1

As Table 2 shows, White found the WDMET data described the chance of a wound from small arms was high. A wound to the head from any source was more likely to be fatal than to the chest or abdomen. Data on Table 2 supports the current strategy of protecting the head as a priority, then the chest and thirdly the abdomen.

3. Operation Desert Storm

The nature of warfare in Operation Desert Storm (ODS), in Iraq in 1991, was different from Vietnam, with a high armoured presence used in a desert environment. Carey (1996) reviewed data on admissions to U.S. Army Seventh Corps hospitals between February 20 and March 10 1991. The study considered the 143 admissions who survived their initial wounding by either bullet or fragment. Ninety five percent of these admissions were from fragmentation wounds and only 7 cases (5%) were from bullet wounds. The high incidence of fragmentation wounds was due to the increased chance of survival from a fragmentation wound. Those dead on arrival from bullet wounds were not brought into the hospital. Carey suggests that this reflects the nature of armoured combat, with increased fragments from artillery and less close contact between infantry.

Table 3: Wound distribution during ODS (Carey, 1996). NB: Many soldiers received multiple wounds

Wound location	Number of soldiers with this wound (& % of total)
Extremities only	93 (65%)
Extremities + other	32 (22.4%)
Head total	24 (17.3%)
Chest total	8 (5.8%)
Abdomen total	13 (9.3%)

As Table 3 shows, nearly 90% of soldiers treated received extremity wounds. Carey compared the percentage of chest wounds in ODS with those of other conflicts and noted the percentage figures were lower in ODS. He also noted that the percentage of wounds to the abdomen (which was not protected) was similar to other conflicts. From this finding

Carey argued that the ballistic protective vests worn by US soldiers offered effective protection. Carey also declared that the Aramid helmet worn offered effective protection, since only two head injuries were recorded that subsequently proved fatal when the trend from other conflicts would predict four head wounds for the same sample size. It is doubtful, however, that a solid conclusion should realistically be made when comparing such infrequent incidences, using such small sample sizes.

Of the 71 hospitalisations during ODS reported by Gauker and colleagues (1994) 4 were head wounds and 3 were trunk and neck wounds. Mention was not made if the wounds were inflicted from a bullet or fragment. This data shows a higher ratio of head to torso wounds than the Carey data, but since the dataset is so small, little can be concluded from this.

4. Northern Ireland

The typical conflicts in Northern Ireland have been acts of terrorism and urban skirmishes. Victims of these actions were often civilians as well as military forces. Between 1972 and 1980 casualty admission data at the Craigavon Area Hospital, County Armagh, were collected on victims of terrorist activities admitted alive to the hospital (Pyper and Graham, 1983). Their results are shown in Tables 4 and 5. Of the 454 patients, 75% were victims of bomb blasts and the remaining 25% received gunshot wounds. The vast majority of these patients were civilians. No mention is made of the percentage of victims who were members of the security forces, and in particular no mention was made of the effectiveness of body armour.

Table 4: Distribution of wounds and abrasions in bomb victims (from Pyper and Graham, 1983)

Site of Injury	Wounds	Abrasions
Head and Neck	55	48
Upper Limb	39	41
Trunk	19	23
Lower Limb	75	87

Table 4 shows that the number of wounds to the head and neck is disproportionate to the size of the head as a target. No explanation for this is given by Pyper and Graham. The large number of wounds to the lower limbs is in part due to the effect of road mines and the practice of "kneecapping".

Table 5: Distribution of sites of injury of all gunshot victims (from Pyper & Graham, 1983)

Site of Injury	Number of Injuries	% (n = 115)
Head and Neck	16	14
Upper Limb	30	26
Trunk	35	30
Lower Limb	55	48

Gunshot wounds were more likely to cause injury to the trunk than bomb fragments (30% versus 10.8%). Of those who received head injuries, only 5 reached hospital alive and only 1 survived treatment. The most common cause of early death was head injury.

5. Lebanon War

Grofit and colleagues (1996) reviewed the location on the body of fatal missile wounds in an effort to improve the design of new military personal body armour. One hundred and sixty four soldiers received 405 penetrating missile wounds. Referring to Table 6, almost 72% of these wounds were from shrapnel, the remainder from high velocity bullets.

Table 6: Number of wounds (and % of total) according to military assignment and missile type (Grofit et al. 1996)

Missile	Infantry	Tank	Logistics & Other	Total
Bullets	62 (39%)	27 (15.9%)	26 (34.2%)	115 (28.4%)
Shrapnel	97 (61%)	143 (84.1%)	50 (65.8%)	290 (71.6%)
Total	159 (100%)	170 (100%)	76 (100%)	405 (100%)

Infantry were more likely to sustain bullet wounds than the other military assignments, with nearly 40% of all wounds from bullets. Overall 28% of wounds were from bullets. In addition to the data shown in Table 7, 91.1% of all wounds were to the front of the body.

Table 7: Wound Location of 164 soldiers who died of penetrating injuries (Grofit, et al., 1996)

Body location	Shrapnel injuries	Bullet injuries
Face	57 (19.6%)	80 (22.2%)
Cranium	19 (6.6%)	36 (8.9%)
Neck	10 (3.4%)	11 (2.7%)
Torso	138 (47.6%)	183 (45%)
Limbs	66 (22.8%)	85 (20.9%)

Of the penetrating shrapnel injuries that hit the head, three-quarters hit the face. The cranium was considered to be protected by the helmet. The face was unprotected, which may, in part, explain the high face penetration statistic. Two-thirds of face wounds were caused by bullets, presumably because bullets were more likely to penetrate the helmet than shrapnel.

Table 8: Wounds by body location as a percentage of total body surface area and wound density as a ratio of hits to body surface area (Grofit, et al., 1996)

Body Location	Total Body Surface Area	Density Rating
Face	3%	7.3
Cranium	3%	2.9
Neck	3%	0.9
Torso	37%	1.2
Limbs	54%	0.39

Of note from Grofit's study is the assessment of hit location probability and relative body surface area, as shown in Table 8. The results indicate that the face was 7.3 times more likely to be hit by either shrapnel or bullets than it would receive by chance. The head (excluding the face) was 2.9 times more likely to receive a penetrating missile wound. This data indicates that the head and face are targeted in preference to other body parts (either by choice or possibly as a product of the exposure of the head in armoured vehicles, or just being exposed when the rest of the body is in cover).

6. Croatia

Data on patients treated at the Vinkovci General Hospital, Vinkovci, Croatia, between May 1, 1991 and July 1, 1992 were collected and reported by Sebalj, Hodalic, Svagelj, Sebalj and Sebalj (1999). This dataset represents all patients treated at the hospital during the Serbian-Croatian war. The hospital was minutes away from the front line of a Serbian offensive and received heavy shelling. The conflict in the region was characterised by repeated heavy artillery bombardment.

The data reflects patients taken to the hospital alive, of which there were 1,211 during the 15 months of conflict. Two thirds of patients seen were either Croatian military or police, the remaining being civilians, including the elderly and children. Another 344 dead bodies were taken to the hospital, but this does not reflect the total amount killed in action and they were not included in this dataset. The vast majority of injuries seen at this hospital were wounds caused by shell fragments (90%), with bullet wounds being relatively infrequent (3%). The remaining wounds were caused by mines or burns.

Table 9: Wound location of 1211 patients treated at Vinkovci General Hospital, Vinkovci, Croatia, between May 1, 1991 and July 1, 1992 (Sebalj, et al., 1999)

Location of Injury	Penetrating	Non-penetrating	All (% of total)
Head	47	77	124 (10.2%)
Spine	n/a	n/a	20 (1.7%)
Thorax	80	101	181 (14.9%)
Abdomen	77	28	103 (8.5%)
Pelvis	13	120	133 (11.0%)
Arm	n/a	n/a	278 (23%)
Leg	n/a	n/a	553 (45.7%)

Referring to Table 9, nearly 70% of all wounds were to the limbs. About 15% of injuries were suffered to the thorax, and 10% to the head. There was a shortage of helmets in the first phases of the conflict and those with helmets were reportedly reluctant to wear them. No data are available on the distribution of wounds according to type of injury or cause of injury, although the vast majority of these injuries were caused by shrapnel from artillery bombardment. Of the 1211 patients treated, 51 died. There is no breakdown of the direct cause of death, the division of military and civilian statistics, or location by weapon type.

7. Discussion and Conclusion

There is a need to consider the head as a high priority area for protection. In Vietnam wounds to the head were more likely to be fatal than wounds to any other part of the body (White, 1969). In both Northern Ireland and Lebanon the head was very susceptible to wounding considering its relatively small size, receiving up to 7 times more wounds than would be expected given the size of the head. In reviewing data on wounds from different conflicts, Carey (1996) reported that 34-46% of all fatal combat wounds are head wounds.

Carey (1996) also reported that fragmentation wounds accounted for 65-84% of all missile wounds in WW2, 68% in Korea and 50% in Vietnam. Table 9 shows that the percentage of fragmentation wounds received in the conflicts mentioned was between 71.6% and 95%. The figure of 45% by Carey and colleagues (1982) is influenced by the fact that all wounds were to the head, which was more likely to be fatal than bullet wounds to other parts of the body (see Table 2.).

*Table 10: : Summary of datasets reviewed. * = head wound was a criterion of inclusion into this dataset*

Conflict	Reference	Number of Injured	% Frag Wounds	% Head Wounds	Type of Victim
Vietnam	Carey et al. 1982	129	45%	100%*	Military
	Gauker et al. 1994	70,943	n/a	14%	Military
Operation Desert Storm	Carey 1996	143	95%	17.3%	Military
	Gauker et al. 1994	71	n/a	5.6%	Military
Northern Ireland	Pyper & Graham 1983)	454	75%	26.6% (frag) 15% (GSW)	Mostly Civilian
Lebanon	Grofit et al. 1996	164	71.6%	26% (frag) 29% (GSW)	Military
Croatia	Sebalj et al. 1999	1,211	90%	10.2%	2/3 Military 1/3 Civi

Carey notes "The WDMET data indicate that the U.S. helmet employed in Vietnam was ineffective in defeating the 7.63 bullet at common combat ranges... It would appear that the energies associated with military bullets are so great that it is unlikely that practical helmets will easily be developed to protect against bullets" (Carey et al., 1982, p. 354). Although helmet technology has improved since the Vietnam war, and the ballistic protection offered by modern helmets is superior to that of the metal helmets used by the US Army during Vietnam, new helmets will not stop a high velocity round at common combat ranges.

As the datasets presented here illustrate, the combat helmet offers limited protection. Almost half of bullets that hit also penetrated the metal helmets worn in Vietnam. Almost a third of all wounds to the head struck below the level of the helmet. In Lebanon, that figure was higher, with three-quarters of all head shots received in the face.

However, one repeated finding was that helmets offered significant protection against fragmentation. In the sample of head injuries reported by Carey et al. (1982) not a single fragment that hit a helmet caused a fatality, even though some did penetrate the helmet. The helmet either deflected the fragment or significantly reduced its velocity.

The properties of the 'best' helmet are determined by weighing up the protection offered against the ergonomic burden. There is a high relationship between the weight of the helmet and the level of ballistic protection offered. There is also a relationship between the neck fatigue and the weight of the helmet (Ashrafiuon, Alem & McEntire, 1997, Philips & Petrofsky, 1983). A heavy helmet has two disadvantages. Firstly it produces fatigue of the neck. This is especially true when other equipment is attached, such as night vision goggles, communications systems and gas masks. Secondly the heavier the helmet, the greater its propensity to move around on the soldier's head when the head moves rapidly.

In their concluding comments, Grofit and colleagues made recommendations concerning modifications to current body armour, the most significant of which was suggested modifications to the helmets. Since most of the damage to the cranium was suffered on the frontal bones (top of head), Grofit argued that a helmet with increased protection on the front and less on the back would increase protective ability without significantly increasing weight. Whilst the face had a very high hit ratio, protection of the face is difficult. Grofit recommended a brim to the helmet to reduce injury from missiles coming from above. A lightweight and transparent face shield could improve protection but could present operational limitations. Grofit recommended a chin cover to protect the lower face.

In the study of the Lebanon conflict, Grofit noted that almost half of all wounds were received on the torso. Seventy five percent of these torso wounds were located in a specific area: the front-mid torso. Based on this result Grofit recommended that a protective device able to withstand high-velocity bullet impact be located at the front-mid torso.

Until such time that helmets can be made to protect against high velocity bullet impact it seems reasonable only to ensure protection against fragmentation and optionally adopt some design recommendations from Grofit.

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19. ABSTRACT
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