Author: Hoencamp, Rigo
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Chapter 4. Impact of explosive devices in modern armed conflicts: in-depth analysis of Dutch battle casualties in Southern Afghanistan

Rigo Hoencamp; Eelco P. Huizinga; Thijs T.C.F. van Dongen; Floris J.Idenburg; Arul Ramasamy; Luke P.H. Leenen; Jaap F. Hamming

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ABSTRACT

Background: To improve care for injured service members, we have analyzed the patterns and mechanisms of all Dutch battle casualties. This study represents an in-depth analysis of all Dutch battle casualties during our participation in the ISAF mission as lead nation (2006-2010) Southern Afghanistan.

Methods: Participants were selected from the trauma registry at the Dutch role 2 Enhanced Medical Treatment Facility, where they fitted the criteria Dutch battle casualty between August 2006 and August 2010.

Results: The trauma registry query resulted in 203 Dutch battle casualties, with 1.7 wounds per battle casualty. The battle injuries were predominately caused by explosions (83%). The wounding pattern was as follows: head and neck (30%), thorax (9%), abdomen (15%), upper extremity (16%) and lower extremity (30%). The mean AIS and ISS were 3 (range 1-6) and 11 (range 1-75), the case fatality rate 9%, the percentage killed in action 16%, and the percentage died of wounds 1%.

Conclusions: Explosive devices accounted for the majority of battle casualties, a higher percentage than in previous wars. Knowledge of the type of injuries may also be valuable in treating casualties from natural disasters or mass casualty situations. An integral multinational joint approach is highly recommended to develop more effective protective equipment and body armour, with special focus on head and neck and extremity protection. Prospective registration in a standardized system of data collection, encompassing all echelons of the medical support organization should be implemented.

INTRODUCTION

The importance of understanding battle (combat) injuries, as well as their precipitating mechanisms has generally been recognized and several reports have already been published concerning the incidence and character of battle injuries sustained by battle (combat) casualties (BCs)[1-6]. Comparison is only possible using clear battle casualty definitions[6]. The Iraq and Afghanistan armed conflicts have resulted in a large number of combat-related casualties, like in the Korea and Vietnam wars, but with injury patterns differing from previous theatres of war[7]. Explosive devices are the signature threat of current military operations, and prevention of casualties and major injuries are the major concern[1,2]. The Netherlands (NL) were the lead nation in the Uruzgan province (2006-2010), deploying approximately 17,000 military service members[8], as part of the North Atlantic Treaty Organization (NATO) led International Security Assistance Force (ISAF) mission in Southern Afghanistan. The main component of the Task Force Uruzgan was located at the multi-national base Tarin Kowt (MBTK). It was composed of 1,200 Dutch service members, and possessed its own medical treatment facility (role 2 MTF NL) containing approximately 50 multinational medical service members. The role 2 MTF NL was configured with two emergency resuscitation tables, one operating room, two ICU beds and fourteen regular nursing beds (Figures 1 and 2).

Figure 1. *The Dutch role 2 Medical Treatment Facility in Uruzgan, Afghanistan, reinforced by a ballistic protection wall (Hesco-Wall).*

Figure 2. *The operation room at the Dutch role 2 Medical Treatment Facility in Uruzgan, Afghanistan.*

Hoencamp et al.[1,2,9] described the total incidence of all casualties (~75% caused by improvised explosive devices [IEDs], and at least n=157 Dutch BCs) and challenges during the treatment of casualties at the role 2 MTF NL. The Dutch government published a report describing a different number of Dutch battle casualties (n=144)[8]. This discrepancy shows the difficulty in the usage of (NATO) battle casualty definitions and registration information. Coalition partners also reported poor registration of (pre-) hospital data, leading to missing information. Therefore, the United States of America (US) established in 2004 the Joint Theater Trauma Registry (JTTR, now known as the Department of Defense Trauma Registry [DoDTR]) as a standardized system of data collection, designed to encompass all the echelons of the Medical Support Organization[10,11].

To date, an in-depth analysis of the Dutch BCs treated at role 2 MTF NL, with special emphasis on IEDs, has not been compiled, partly due to the lack of a complete and standardized trauma registry. The goal of this study was to conduct a detailed analysis of the Dutch BCs, and to lay the foundation for a (Dutch) military medical trauma registry. Ultimately, our findings in epidemiological trends of combat injuries may provide insight to the prevention and treatment of such injuries. Structural data on the type of injuries treated may also be useful in prevention, development of protective equipment and pre-deployment requirements of the Dutch armed forces.

METHODS

This study was approved by the Ministry of Defense (MOD), the Institutional Review Board and the Medical Ethics Committee of Leiden University, the Netherlands. Battle casualties were defined as service members being injured as a direct result of hostile action, sustained in combat or sustained going to or coming from a combat mission[6]. For the purpose of this study, we included individuals killed or wounded accidentally by friendly fire directed at a hostile force, or what was thought to be a hostile force (blue on blue). We excluded (1) self-inflicted wounds, (2) wounds or death inflicted by a friendly force when the serviceman was absent without leave, or was a voluntary absentee from his or her place of duty, and (3) psychological injuries. Individuals who died of wounds before receiving treatment at a MTF were deemed killed in action (KIA). Service members who survived their injury until arrival at a MTF were defined as wounded in action (WIA). The WIA group was further subdivided into service members who died of wounds (DOW) from combat injuries after reaching a MTF, those treated and returned to duty within 72 hours (RTD), and those aero medically evacuated (STRATEVAC) out of theatre. The percentage KIA was defined by the following equation[12]: $\%KIA = KIA / [KIA + (WIA\text{-}RTD)]\times100$. The percentage DOW was defined by the following equation[12]: $\%DOW = DOW / (WIA\text{-}RTD)\times100$. The case fatality rate (CFR) was defined as the percentage of fatalities among all wounded and is defined by the following equation[12]: $CFR = (KIA + DOW) / (KIA + WIA)\times100$. The percentage per deployed service member (PPDSM) was calculated as overall score and per branch of service: PPDSM = BC/ total deployed service members (or per branch of service) ×100. Participants eligible for this study came from a general digital admission database of the MOD, and they fitted the criteria ‘BC between August 2006 and August 2010’. A follow-up period of 30 days (complication and died of wounds) was used. We performed an inventory of records in the database of the trauma registry at the role 2 MTF NL and merged the Dutch battle casualty demographics with information from the medical records to identify the mechanism and type of injury. All information was collated in a specifically designed electronic database. The BCs were divided into five rank groups namely; junior enlisted (E1-E4), senior enlisted (E5-E9), warrant officers (WO1-WO2), junior officers (O1-O3) and senior officers (O4-O10). In calculating the mechanism of injury (MOI), and anatomical distribution of wounds (AD), we excluded the unknown cases to correct for missing data. Statistical analyses were performed using a software package, SPSS (Version 20, IBM Corporation, Armonk, New York). The categorical variables were analyzed by their absolute and relative frequencies in percentages. The association between two categorical variables was calculated by applying the Pearson χ^2 squared test. In all cases, $p < 0.05$ was considered statistically significant. The severity of the injuries in this study was scored in the Abbreviated Injury Scale (AIS)[13], the Injury Severity Score (ISS)[14] and expressed in mean and range.

RESULTS

Battle casualty statistics

During the study period a total of 199 Dutch battle casualties (WIA-DOW-RTD-KIA) were treated at the role 2 MTF NL (Table 1). Between August 2006 and August 2010, approximately 17,000 military service members (~15,000 Army, ~250 Navy, ~600 Marines, ~1,000 Air force and ~150 Military Police) were deployed, 25% of them multiple times (Table 2). The combined study population was predominantly male (99%, 197/199), with a mean age of 24 years. The CFR was 9.5%, the percentage KIA 16.5%, and the percentage DOW 1.1%. The distribution of BCs by branch of service was significantly different ($p<0.0001$) across all years studied with a greater absolute percentage (85.1%) of Army service members sustaining battle injuries in Afghanistan. The Army (0.9%) and Marine Corps (3.5%) demonstrated the highest overall percentage of BCs per deployed service member. When examining the distribution of BCs by rank group, significant differences ($p<0.0001$) were noted in the 72.4% (144/199) junior enlisted, 17.1% (34/199) senior enlisted, 0.5% (1/199) warrant officers, 5.5% (11/199) junior officers, 1% (1/199) senior officers, and unknown cases 2% (8/199).

Mechanism of injury and anatomical distribution of wounds

Explosions (83.9%) were the dominant mechanism of injury, being significantly higher than those caused by gunshot wounds (6.0%, ($p<0.0001$)) (Table 3), from small arms fire. Roadside IEDs accounted for the highest casualty rate per incident (CR). In nine major incidents the CR was ≥5, the “on target” roadside IEDs seemed to follow an “all or nothing pattern”. Flat bottom vehicles were struck in all high CR cases. The distribution of casualties showed a significantly higher peak in the spring and summer periods (Figure 3).

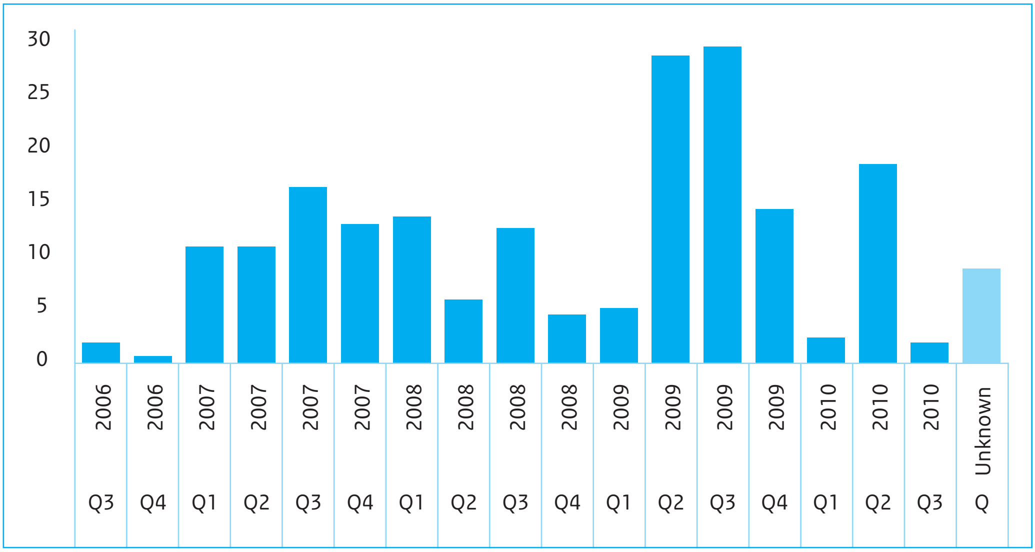

***Figure 3:** Distribution of battle casualties in relation to time of year (n=199).*

Q indicates quarter of year; *Q unknown* represents the unknown case dates.
The vertical axis represents the number of battle casualties per quarter of year, the horizontal axis represents the quarters from Q3 2006 till Q3 2010, the last column represents the unknown incident dates n=9.

A total of 199 BCs sustained 308 wounds, resulting in 1.7 (calculated without the unknown cases wounds per BC (Table 4)). The anatomical distribution of wounds was calculated with the unknowns excluded in the WIA-RTD group (15/199). Head & neck, and extremity injuries were most common among all groups. Ocular injuries accounted only for 3.0% (6/199) in all BCs. There was a significant difference ($p<0.0001$) in thoracic injuries when comparing the KIA and DOW group with the WIA group. The mean AIS (body region with highest AIS score) and ISS were 3 (range 0-5) and 11 (range 1-43) in the WIA group.

Battle casualty type	Number	Percent
WIA	181	90,9
STRATEVAC	91	45.7
RTD	89	44.7
DOW	1	0.5
KIA	18	9.1
BC (WIA + KIA)	199	100
CFR	NA	9.5
Percentage KIA	NA	16.5
Percentage DOW	NA	1.1

***Table 1:** Dutch combat casualty statistics for the armed conflict in Southern Afghanistan (2006-2010).*

WIA indicates wounded in action; *STRATEVAC:* strategic aeromedical evacuation; *RTD:* Return to duty; *DOW:* died of wounds; *BC:* battle casualty; *KIA:* killed in action; *CFR:* case fatality rate; *NA:* not applicable.

Unit	Number	Percent	PPDSM
Army	131	85.1[a]	0.9[a]
Navy	0	0[a]	0[a]
Marines	21	13.6[a]	3.5[a]
Air force	2	1.3[a]	0.2[a]
Military police	0	0[a]	0[a]
Unknown unit	45	NA	NA
Total	**199**	**100**	**1.2[a]**

***Table 2:** Casualty demographics per unit (n=199).*

PPDSM indicates percentage per deployed service member; *NA:* not applicable.
[a]The percentages are calculated n=154, excluding the unknown unit (during deployment) cases (n=45).

MIO	WIA RTD N (%)	WIA STRATEVAC N (%)	KIA N (%)	Total N (%)
GSW	6 (50.0)	4 (33.3)	2 (16.7)	12(6.0)
Explosion	75 (44.9)	78 (46.7)	14 (8.4)	167 (83.9)
IED	68 (46.0)	68 (46.0)	12 (8.1)	148 (74.4)
Rocket/Grenade	4 (28.6)	9 (64.3)	1 (7.1)	14 (7.0)
Mortar	3 (60.0)	1 (20.0)	1 (20.0)	5 (2.5)
Other	8 (40.0)	10 (50.0)	2 (10.0)	20 (10.1)
Total	**89 (44.7)**	**92 (46.2)**	**18 (9.1)**	**199 (100)**

Table 3: *Primary mechanism of injury (n=199).*

MIO indicates mechanism of injury; *GSW:* Gunshot Wounds; *IED:* improvised explosive device; *Other* (=motor vehicle accident, blue on blue, musculoskeletal injuries during patrol, unknown); *N:* number; *WIA:* wounded in action; *RTD:* Return to duty; *STRATEVAC:* strategic aeromedical evacuation; *KIA:* killed in action.

AD	WIA RTD N (%)	WIA STRATEVAC N (%)	KIA N (%)	Total N (%)
Head/ neck	36 (39.5)	45 (26,8)	18 (36.8)	99 (32.1)
Thorax	5 (5.5)	11 (6.6)	8 (16.3)	24 (7.8)
Abdomen	13 (14.3)	19 (11.3)	8 (16.3)	40 (13.0)
Lower extremity	23 (25.3)	58 (34.5)	10 (20.4)	91 (29.5)
Upper extremity	14 (15.4)	35 (20.8)	5 (10.2)	54 (17.5)
Unknown	15 (100)	0 (0)	0 (0)	NA
Total wounds	**91 (29.6)[a]**	**168 (54.5)**	**49 (15.9)**	**308 (100)[a]**
Mean wounds per BC	1.2[a]	1.8	2.7	1.7[a]
AIS mean (range)	3 (0-3)	4 (1-5)	NA	3 (1-5)[b]
ISS mean (range)	3 (0-9)	11 (1-43)	NA	11 (1-43)[b]

Table 4: *Anatomical distribution of injury (n=199).*

AD indicates anatomical distribution; *BC:* battle casualty; *AIS:* Abbreviated Injury Scale; *ISS:* Injury Severity Score; *N:* number; *WIA:* wounded in action; *RTD:* Return to duty; *STRATEVAC:* strategic aeromedical evacuation; *KIA:* killed in action; *NA:* not applicable.

[a] The mean anatomical distribution of wounds is calculated on n=74 WIA RTD, excluding the unknown cases (n=15).

[b] The AIS (body region with highest AIS score) and ISS were calculated without the KIAs.

DISCUSSION

This study is the first in-depth analysis of all Dutch battle casualties from the ISAF mission to Southern Afghanistan, as contained in the trauma registry (2006-2010). Battle injuries were mainly (84%) caused by explosions with casualties often sustaining wounds to multiple anatomical body regions, this compares to reports by coalition partners[1-6,15,16]. One of the significant difficulties in comparing epidemiological casualty data from different conflicts is the variation in the used battle casualty definitions as well as difficulties in obtaining full data capture in austere combat environments. A valid comparison is only possible using strict (NATO) battle casualty definitions[6]. Collaboration of the Dutch armed forces in a validated registration system (e.g. DoDTR) or integration in the Dutch national trauma registry seem realistic opportunities. Improvements in prevention and protective equipment (body amour and vehicle protection) will only be successful if we continue to anticipate on the usage of these weapons of terror in the future by opposing militant forces. The high incidence shows the importance of a thorough understanding of the biomechanics of (improvised) explosive devices and the wounds inflicted by these devices[17-21]. Ramasamy et al.[18] described the mechanism of (improvised) explosive devices extensively; injuries from explosions are classified into four categories: primary, secondary, tertiary and quaternary blast injuries (Textbox 1). Due to the lack of a trauma registry, it was not possible to classify the Dutch BCs in these categories.

Textbox 1: Subgroups of blast injuries

Primary blast injuries are caused by the sudden increase in air pressure after an explosion. Air-containing organs (e.g. middle ear, lungs, and gastrointestinal tract) are susceptible to the effects of the blast wave. Eardrums may rupture at pressures of 2 psi, whereas pulmonary effects are seen at 70 psi. Exposure to pressures above 80 psi is associated with death in more than 50% of cases. Tissue susceptibility to the effects of primary blast is inversely related to the third power of a victim's distance from the explosion. Consequently, the presence of severe pulmonary damage is evidence of the proximity of the victim to the explosion. Secondary blast injuries occur when bomb fragments or nearby debris are energized by the explosion and cause injury by penetrating trauma. Tertiary blast injury is caused when the casualty is thrown by the explosion and collides with nearby objects. Quaternary blast injury is a miscellaneous group (e.g. thermal effects of the explosion and psychological injuries).

The nature of blast injuries has become more apparent in recent times despite occurrence in every conflict of the twentieth century. It is the multi-modal mechanism through which blast injuries are caused that drives the development of complex solutions (e.g. in-vehicle blast scenario) in order to develop evidence-based clinical management[18]. Army service members sustained the absolute highest number of BCs, the Marines the highest relative number, this can be explained by the scope of operations in these units. There was a significant increase in wounds in the head and neck region and a significant decrease in thoracic wounds compared with previous wars[22-25] which could be attributed to improvement in protective body armour in recent years. Extremities remain relatively unprotected by Dutch (NATO approved) body armour.

The thoracic injuries were associated with a higher AIS and ISS score and thus, not surprisingly, significantly more common in the KIA and DOW group. Interestingly, serious ocular and genitalia injuries have been commonly associated with IED incidents[26], however they were only sporadically seen in our series. The use of protective body armour, especially ballistic eye protection, could be an explanation for this difference in anatomical distribution of wounds. The different operational tasks and area of operations could possibly be another explanation, but beyond the scope of this study. The use sniffer dogs, also might have influenced the incidence of IEDs of mechanism of injury. Their casualty rate is approximately 25%, but they have also been very useful in detecting IEDs. A combined analysis of somatic and psychological effects of blast injuries (e.g. traumatic brain injuries) warrants further assessment. The pre-hospital phase seems to be the most important phase in the medical support organization to improve the outcome for BCs[27-30]. In Europe (and thus also in the Netherlands), the incidence of penetrating and blast trauma is low[31,32]. Medical specialist training and education for deployment to austere environments, encountering multiple injured patients with high-energy transfer fragment, projectile and blast wounds that require an assortment of damage control and definitive operative competencies should be developed, because the spectrum of injuries is unparalleled in standard civilian practice[33]. Knowledge of this type of injuries is also valuable in treating casualties from natural disasters or mass casualty situations (e.g. Boston marathon bombing). Non-Governmental and civilian organizations (e.g. political, law enforcement and commercial companies) should be part of this integration process. An integral multinational joint approach is highly recommended. The Dutch experiences in Afghanistan have shown that the insurgents adapt their methods swiftly and effectively to our operational tempo and standard operational procedures (e.g. higher explosive charges after the replacement of flat bottom vehicles with V-shaped bottom vehicles). The major threat in current armed conflicts are (roadside) IEDs. Besides protective equipment, the best forms of prevention are tactically avoiding threat (when possible and applicable), and early adaptations. The intelligence and surveillance services should provide concise information for optimal operational (battle) planning. The aspect of terror; not killing but severely wounding the coalition forces, is the key strategy of the insurgents. Static and heavy vehicle supported operations make us vulnerable for IEDs in asymmetric armed conflicts. Tactical adaptions ("out of the box solutions") are required the keep momentum and the element of surprise. Weather conditions and vegetation in relation to time of year were predictors for a higher incidence of (roadside) IEDs. This can be explained by the weather (e.g. ground conditions and rain), and vegetation changes in the spring and summer for good concealment of IEDs. In order to prevent the insurgents from succeeding in their aim of disrupting coalition forces, we should limit predictability and adapt to the local situation. Prevention of injuries from planned attacks by good mission command ("creative auftragstaktik") is only possible if good intelligence is available.

There are certain limitations to our study. First, the absence of a standardized system of data collection, and the inevitable resulting delay in reporting these statistics. Secondly, because of missing information, inaccuracy could be present in calculating the AIS and ISS in the RTD group. Thirdly, missing information could have led to an underestimation of the total number of WIA-RTD. Fourthly, retrospective cohort studies are sensitive to bias and battle casualty definitions significantly affect casualty analysis results. The inclusion of KIA and RTD in any analyzed cohort will affect the distribution of wounds and mechanisms of injury. Clearly defining the studied population is necessary to make valid comparisons and draw meaningful conclusions. The ideal registry is described in the work of Belmont et al.[34]. Although reports from previous armed conflicts have been published after the completion of combat operations by NATO coalition partners, this study represents an in-depth analysis of all Dutch battle casualties during our participation in the ISAF mission as lead nation (2006-2010).

In conclusion, the wounding patterns observed in Dutch BCs in Southern Afghanistan (2006- 2010) differed from previous NATO conflicts. Explosive devices accounted for the majority of battle casualties, a higher percentage than in previous wars. Knowledge of the management of this type of injuries may also be valuable in treating casualties from natural disasters or (terror) mass casualty situations. An integral multinational joint approach is highly recommended to develop more effective protective equipment and body armour, with special focus on head and neck and extremity protection. Prospective registration in a standardized system of data collection, encompassing all echelons of the medical support organisation should be implemented. Collaboration of the Dutch armed forces in the DoDTR or integration in the Dutch national trauma registry seem good opportunities in achieving this aim.

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