

Comparison of Combat and Non-Combat Burns From Ongoing U.S. Military Operations¹

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Background. Military burns result from either combat or non-combat causes. We compared these etiologies from patients involved in ongoing conflicts to evaluate their impact and provide prevention recommendations.

Methods. All military patients with significant burns treated at the United States Army Institute of Surgical Research from April 2003 to May 2005 were reviewed. Injuries were categorized as having resulted from combat or non-combat causes. Demographics, burn severity and pattern, mortality, and early outcomes were compared.

Results. There were 273 burn patients seen with 63% injured in combat. A high early rate of non-combat injuries was noted. Feedback on non-combat burn prevention was provided to the combat theater, and the incidence of non-combat burns decreased. Mean age and time from injury to admission did not differ. The majority of combat injuries resulted from explosive device detonation. Waste burning, ammunition handling, and gasoline caused most non-combat injuries. Combat casualties had more associated and inhalation injuries and greater full-thickness burn size; total body surface area burned was equivalent. The hands and the face were the most frequently burned body areas. Mortality was 5% in combat and 2% in non-combat patients. The majority of survivors in both groups returned to military duty.

Conclusions. The disparity in full-thickness burn size and incidence of inhalation and associated injuries resulted from differing mechanisms of injury, with explosions and penetrating trauma more com-

mon in combat wounds. Despite the severity of combat burns, mortality was low and outcomes generally good. Non-combat burns are preventable and have decreased in incidence. © 2006 Elsevier Inc. All rights reserved.

Key Words: burns; military trauma; prevention; epidemiology.

INTRODUCTION

Burns are a frequent source of injury in military operations, typically comprising 5 to 20% of wounds incurred during conventional conflicts [1–3]. Military burn injuries occur either during combat operations as the result of direct enemy action, or during non-combat situations, with their cause unrelated to enemy activity. During the Vietnam War the non-combat component accounted for over half of the burns seen, indicating a significant role of such wounds on the overall burden of military burns [4, 5].

Military burns have a broad impact that ranges from individual patients to the overall status of military operations. According to current United States military medical doctrine, burn casualties are triaged in a standard fashion according to the severity of all their injuries, both burn and non-burn. Standard burn center transfer criteria are used to determine whether patients with non life-threatening burns will be transferred out of the combat theater to a military burn center. Casualties then face a course of treatment and rehabilitative care accordant to the severity of their burn injury [1]. The result is a high percentage of burn casualties being removed from their roles in support of the military operation for long periods of time to receive specialized burn care.

The United States Army Institute of Surgical Research (USAISR) was established by the Department of the Army in 1943 as the Surgical Research Unit. As

¹ The opinions or assertions contained herein are solely the views of the authors and should not be construed as official or reflecting the views of the Department of Defense or United States Government.

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the threat of nuclear war emerged in the 1940s and 1950s, the USAISR's research and clinical focus became the study and treatment of burns. The USAISR remains the only military burn center in the United States, and is the sole burn referral center for all U.S. military burn casualties. Given the historical impact of military burn injury on operations, we designed this study to determine the epidemiology and impact of both combat and non-combat burn injuries incurred during ongoing U.S. military conflicts. This type of analysis has not been carried out for previous conflicts. The aim of the study was to determine the differing aspects of these types of injuries and to provide evidence-based recommendations for their prevention and treatment. As the sole burn referral center for United States military burn casualties, the USAISR was uniquely suited to carry out this analysis.

PATIENTS AND METHODS

Following approval from the Brooke Army Medical Center Institutional Review Board, a review of USAISR institutional databases was performed. All military patients evacuated to the burn center from current theaters of operations were identified, beginning with the first evacuated patient in March of 2003 and ending in May of 2005. The cause of each patient's injury was categorized either as having resulted from combat (resulting from enemy action), or as having occurred in a non-combat situation. The use of such categories allowed the assignment of all casualties to one of the two groups.

Epidemiological characteristics of the incidence of burn injuries were examined. For each patient; demographic information, burn size and distribution, aspects of burn center care, the presence of associated injuries, and outcomes were recorded. Univariate statistical comparisons were made between the combat and non-combat groups.

For continuous variables, intergroup comparisons were made using Student's *t*-test, with pooled values for distributions of equal variance and Satterthwaite values for unequal variances. Categorical variables and proportions were compared using the χ^2 and Fisher's exact tests. Statistical significance was attributed to $P \leq 0.05$. Results are expressed as mean $\pm$ standard deviation throughout, with medians and ranges presented where appropriate.

RESULTS

Epidemiology and Demographics

A total of 273 military burn patients wounded in the current theaters of operations and admitted to the burn center during the study period were identified. Of these, 171 (62.6%) were wounded as the direct result of enemy action and were categorized as combat casualties. The mean age of the entire population was 26 ± 7 years, with no difference in age between combat and non-combat casualty groups. As expected in a military population, males predominated, accounting for 265 (97.8%) of the casualties and all of the non-combat patients. Time from injury to burn center admission

did not differ between the combat and non-combat casualties, with a mean interval of 6 ± 5 days for the entire population.

The causes of burns varied between the combat and non-combat patients, with the great majority of combat wounds incurred via explosive mechanisms. The detonation of improvised explosive devices (IEDs) caused 69.6% of combat wounds. Conventional munitions accounted for further 26.7% of combat injuries. Among non-combat burns, the most common causes were incidents involving the burning of waste (24.5%), ammunition and gunpowder mishaps (20.2%), and the misuse of gasoline (17.3%). Other non-combat etiologies included electrical injuries (8.2%), and scald burns (6.4%).

Injury Characteristics

The mean Injury Severity Score (ISS), inclusive of burns, for the entire population was 9 ± 11 (median, 4; range, 1–75). Patients wounded in combat had a mean ISS of 11 ± 13 , which was significantly higher than the 5 ± 7 seen in non-combat casualties ($P < 0.0001$). This difference can be explained by the significantly greater incidence of associated non-burn injuries seen in combat casualties. These were present in 52.1% of combat patients compared to 11.8% of non-combat casualties ($P < 0.0001$). The most common non-burn injuries were to the extremities (51 patients), followed by the chest (38 patients). Inhalation injury was more common in combat casualties as well, occurring in 16.4%, significantly higher than the 5.9% incidence among non-combat patients ($P = 0.01$, Table 1).

Most burns were small in size, and total body surface area (TBSA) burned did not differ between the combat and non-combat casualties (Fig. 1). For the entire population, mean TBSA involved was $13 \pm 16\%$ (median, 7%; range, 0.2–95%). Combat casualties had $15 \pm 18\%$ TBSA burned, compared to $12 \pm 14\%$ for non-combat patients. Combat burns had a greater full-thickness percentage,

TABLE 1

Injury Characteristics in Combat and Non-Combat Burn Patients

	Combat (n = 171)	Non-Combat (n = 102)	P
ISS	11 ± 13	5 ± 7	< 0.0001
Associated injury (%)	52	12	< 0.0001
Burn size (%)			
TBSA	15 ± 18	12 ± 14	NS
Full thickness	8 ± 16	5 ± 12	0.05
Partial thickness	7 ± 7	7 ± 7	NS
Inhalation injury (%)	17	6	0.01

Abbreviations: ISS, Injury Severity Score; TBSA, Total Body Surface Area.

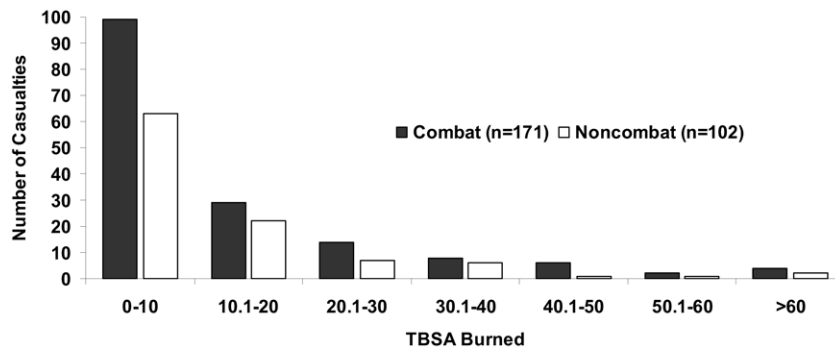


FIG. 1. Frequency histogram representing TBSA burned in the entire population of military burn patients.

however, with a mean of $8 \pm 16\%$. Non-combat casualties had mean full-thickness burns of $5 \pm 12\%$ ($P = 0.05$).

The anatomical distribution of burns was similar between combat and non-combat patients. Burns were seen more commonly on the extremities than on the trunk (Fig. 2). The most frequently affected area in both groups was the hand, with 76.0% of combat and 69.6% of non-combat casualties having hand burns. The face was the next most frequently burned area, and the only area that differed between combat and non-combat, involved in 73.7% of combat and 53.9% of non-combat patients ($P < 0.001$).

Burn Center Care and Outcomes

The overall length of stay at the burn center among all survivors was 24 ± 31 days (median, 13 days; range, 0–242 days). Of the entire population, 91 patients (33.3%) required admission to the intensive care unit (ICU). The most frequent reason for admission to the ICU was the need for mechanical ventilation, and correspondingly 86 patients (31.5%) required mechanical ventilation during their admission. There was no difference between combat and non-combat patients in overall length of stay, though combat casualties trended toward more days in the ICU ($P = 0.08$) and required significantly more days of mechanical ventilation ($P = 0.05$). Reflecting the higher incidence of full-thickness

burns and non-burn injuries, the mean number of operations required among combat casualties was twice that of non-combat patients (Table 2).

At the time of data analysis, ten combat casualties remained inpatients at the burn center, and their information is not included in the presented outcome data. Overall mortality for the population was 3.8%. Although not statistically significant because of the low overall mortality, the mortality rate of combat patients was 5.0% (8 patients), over twice the 2.0% (2 patients) seen in non-combat patients. Outcomes were generally good, with 90.6% of combat and 98.0% of non-combat casualties discharged to their own care. Transfer to an inpatient care facility was required by only four combat patients. An overall assessment of patient disability was made at the time of patient discharge. The finding was uncommon and graded as moderate in 5.6% of combat and 5.9% of non-combat patients and severe in only three combat casualties.

Return to military duty was the most frequently observed military disposition, found in 67.6% of combat and 55.6% of non-combat patients. Many of those returned to duty had medical limitations on their ability to perform military tasks. Some patients remain in the local area of the burn center receiving periodic care, this being the disposition for 17.3% of combat and 18.2% of non-combat patients. Only 4.0% of combat and

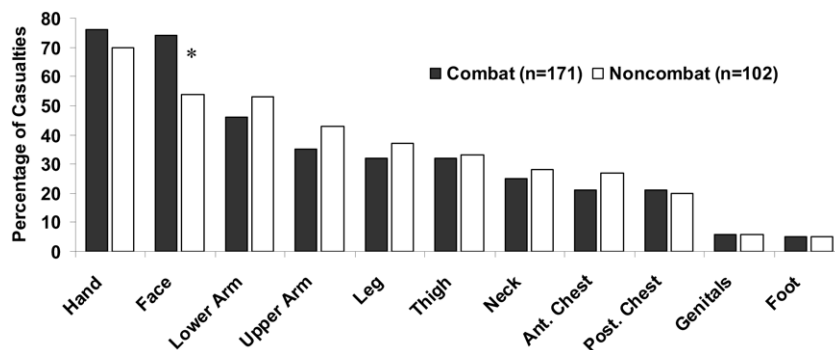


FIG. 2. Frequency histogram representing the anatomic distribution of burns in the entire population of military burn patients. * $P < 0.05$ for the difference between combat and non-combat; Post., posterior; Ant., anterior.

TABLE 2

Burn Center Care in Combat and Non-Combat Burn Patients

	Combat (n = 171)	Non-Combat (n = 102)	P
Length of time:			
Hospital	26 ± 34	28 ± 54	NS
ICU	7 ± 16	4 ± 11	0.08
Ventilator	4 ± 13	2 ± 6	0.05
Operations (total)	2 ± 3	1 ± 2	0.05

Abbreviation: ICU, Intensive Care Unit.

10.1% of non-combat casualties have as yet required discharge from military service because of their injuries, though military dispositions are pending for a number of casualties.

DISCUSSION

Burns remain a significant source of injury for military service members deployed in a theater of operations. We examined the burns occurring during the first 2 years of ongoing United States military operations as belonging in one of two categories by virtue of the circumstances surrounding wounding. Combat burns occurring as the direct result of enemy action tended to be caused by explosions of conventional and improvised munitions and resulted in deeper burn injury, a greater incidence of inhalation injury, and more associated non-burn injuries. Non-combat burns primarily resulted from mishaps occurring with the use of ammunition, fuel, and the burning of waste. The data presented suggest that non-combat burn injuries are not as severe as those incurred in combat. The explanation for the disparity between combat and non-combat burns likely lies in the explosive nature of combat injuries, with an accordingly greater frequency of associated penetrating trauma and deeper burn injury.

The association between even minor associated non-burn injury and mortality from burns has been well described [6, 7]. The mortality in our population was disproportionately skewed toward the more severely injured combat casualties. These accounted for 63% of the patients but 80% of the mortality and the mortality rate for combat patients was over twice that of non-combat casualties.

Similar conclusions were reached by Allen *et al.* in their 1970 report of nearly 2,000 burn patients from the Vietnam War. They reported increased associated injuries with combat burns and in their experience, only 43% of burns were related to combat, but these accounted for 69% of mortality. The authors experienced a similar distribution of injury causes, with landmines, mortars, and rocket-propelled grenades account-

ing for the bulk of combat injuries and gasoline and ammunition misuse accounting for most of the non-combat burns [4].

Because of the preponderance of extremity wounds in combat trauma, many of the associated non-burn injuries in this population are orthopedic in nature. Not infrequently, military burn patients arrive with complex fractures or previous amputations. To address these patients' needs, we have developed close relationships with the orthopedic trauma surgeons at the Level I trauma center that is co-located with the burn center. Additionally, our burn center physical and occupational therapists have taken an active role in these patients' orthopedic rehabilitation. We plan a more comprehensive analysis of the relationship between associated non-burn trauma and outcomes in the military population in a future study when data on more patients is available. The high-energy nature of the injuries encountered in this population have had implications for burn center care in the field of wound reconstruction as well. Many patients have sustained significant soft tissue loss in addition to their burns, and the use of flaps and other types of tissue transfers have been vital in the care of such patients. One frequently seen example has been the need for soft tissue coverage of a fracture site. These cases have required coordination between burn, reconstructive, and orthopedic surgeons.

The overall incidence of burns in current military operations has nearly doubled over the past 2 years, even as the frequency of non-combat burns has decreased. The rate of combat burn injury fluctuates with the operational tempo and level of fighting in theater. As combat operations have progressed over time, the number of combat burns has increased. Non-combat burns have decreased in frequency over the course of the operations. The source of this decrease lies in two factors: the maturation of the combat theater and specific prevention efforts. As an operational theater matures, improvements in the management of waste and the handling of fuel and ammunition occur with the arrival of specialized equipment and personnel. These improvements will decrease the frequency of burn injuries caused by mishaps in these areas. While not true of combat burns, which occur as a consequence of operations, non-combat burns are typically preventable injuries. Early in the conflict, the USAISR noted the high incidence of non-combat burns occurring with the burning of waste. Burn center personnel transmitted their concern about such injuries through the medical chain of command to the combat theater [1]. As operations progressed the incidence of burns because of waste burning decreased; likely resulting from a combination of factors including enhanced command awareness and increasing maturity of the combat theater, with employment of less dangerous means of waste disposal.

The TBSA burned in this military population was similar between combat and non-combat casualties. The mean burn size was small, with most burns covering less than 20% of the TBSA and the majority less than 10%. This distribution is similar to that experienced in historical military conflicts. In Vietnam, 66% of burn patients had less than 20% TBSA involvement and in the 1982 war in Lebanon, 50% of casualties had burns involving less than 10% TBSA [4, 8]. The small average size of the burns seen in this population belies their morbidity. Hand and facial burns predominated in both combat and non-combat casualties. These are among the most difficult burns to care for, and even injuries small in size may have significant long term morbidity and functional consequences [9–11]. The predominance of hand and facial burns has been reported in prior modern conventional military conflicts. Levin and Bornstein identified the phenomenon in a report from the “Six Days War” in the Middle East in 1967 [12]. During the Lebanese war of 1982, over three-quarters of burn casualties with unprotected hands and face suffered burns to these areas [8]. In Vietnam, a significant portion of burn casualties had burns to the hands and face. Allen *et al.* reported that these injuries posed treatment challenges disproportionate to their size [4]. The anatomical distribution of military burns is similar to that seen in the civilian population treated at the USAISR. In a recent evaluation, the frequency distribution of burns to body areas was similar for military and civilian patients but military burns more commonly affected the face and hands.

In the Vietnam War, burns carried a mortality rate of 7.9%, [4] at 3.8%, the current rate is much lower. This likely reflects both a smaller mean burn size as well as improvements in critical care and the employment of a treatment strategy consisting of early excision of burn wounds for patients with the most severe burn injuries. In the current conflicts, even though global assessments of casualties’ functional outcomes at the time of hospital discharge were nearly universally favorable, the impact on military readiness of these injuries is great. Over 30% of combat and over 40% of non-combat patients were unable to return to full military duty. Although few patients have as yet required complete discharge from military service because of their injuries, the even temporary removal of personnel from their units, especially during a deployment, can place significant strain on military readiness. This situation forces units to replace experienced personnel, frequently with those with less experience, or to maintain readiness despite depletion of personnel. Unfortunately, we do not have data on the capacity of our non-career military burned patients to return to their civilian occupations.

Many of those service members who returned to duty did so with medical limitations as a result of their

injuries or ongoing care and rehabilitation. These individuals may not be able to perform their original military functions, thus limiting their unit’s operational effectiveness. An example frequently seen in this population was an infantry soldier who has sustained isolated hand burns and is unable to properly handle and fire a weapon. A soldier in this situation requires retraining and reclassification into a military occupation that he can perform with his limitations. Even the units who had personnel returned to full duty without limitations felt the impact of losing their injured personnel for a period of time inclusive of their evacuation, inpatient treatment, outpatient treatment, and return. Our burn center’s department of rehabilitative services is performing ongoing research into the specific functional limitations and morbidities of both combat and non-combat burns to more fully evaluate the operational consequences of such wounds.

In this population, 11% of burns were isolated to the face and hands, and 8% to the hands alone. The high incidence, great morbidity, and potential preventability of burns to the hands and face in military situations have been identified, and the wider and more consistent use of protective garments has been advocated [13, 14]. The protective potential of burn-protective equipment in military trauma has been well documented. Fire-retardant flight suits made of Nomex (DuPont, Richmond, VA), when properly worn, reduce the incidence and severity of burns associated with military helicopter accidents [15]. Similar garments have been issued to armored vehicle crewmen and have demonstrated similar efficacy, decreasing the severity of burn injury when such vehicles are attacked [16]. In the Israeli experience from the 1982 Lebanon War, the use of flame-retardant gloves alone reduced the incidence of hand burns from 75 to 7% among tank crewmen who sustained burn injury. The incidence of hand burns with glove use decreased from 25 to 2.5% among all injured crewmen [8].

The psychological well being of burned service members is of vital interest to the United States military medical community. At our burn center, we have developed a comprehensive screening and treatment program for the psychological consequences of such injuries. The development of acute stress disorder and post-traumatic stress disorder has been seen, and both pharmacological and cognitive-behavioral techniques are used to address these problems.

The only reliable way to reduce the impact of burn injury on military operational readiness is to prevent the injuries themselves. Most non-combat burns are preventable injuries, and great strides have been made in this area during ongoing operations. Increases in the use of protective equipment, improved facilities and ongoing service member training in activities such as the handling of waste, ammunition, and fuel are vital

to maintaining the low incidence of non-combat burn injury that we have achieved in current operations.

Burns that occur as the result of enemy action are often not preventable. The distribution of burns seen in combat injured casualties likely represents the protective effect of the wounded casualties' clothing and equipment such as body armor. Gloves made from fire-retardant materials are currently advocated and in use by the United States military in ongoing operations [17], and fire-retardant facial protection for use during high-risk operations can be recommended based on the findings of this study. The broader use of such protective garments or devices for the hands and face could significantly reduce the incidence of burns sustained in combat and their routine use might have prevented up to 11% of the burn casualties requiring evacuation from theater to the burn center. Protective clothing and equipment may also result in decreased burn severity, morbidity, and potentially increased return-to-duty rates among soldiers that are burned in combat.

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