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Burns sustained in combat explosions in Operations Iraqi and Enduring Freedom (OIF/OEF explosion burns)☆

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Abstract

Background: Burns comprise 5% of casualties evacuated from Operations Iraqi and Enduring Freedom (OIF and OEF). Many OIF/OEF burns result from the enemy's detonation of explosives. We reviewed these to evaluate mission impact and provide recommendations for improved combat burn protection. Data were compared to those from the Vietnam War.

Methods: All OIF/OEF patients with significant burns are treated at the U.S. Army Institute of Surgical Research (ISR). A review from April 2003 to April 2005 was undertaken. Records were obtained and demographics, burn severity and pattern, and early outcomes recorded.

Results: Two hundred and seventy-four OIF/OEF burn patients were treated, 142 (52%) sustained burns in explosions from hostile action. Age was 26 ± 7 years (mean ± S.D.). Mortality was 4%. The annual rate of combat explosion as a cause for burns increased from 18% to 69%, total body surface area burned increased from 15 ± 12 to 21 ± 23%, injury severity score rose from 8 ± 11 to 17 ± 18, and frequency of inhalation injury rose from 5% to 26%. Improvised explosive devices caused 55% of casualties, car bombs 16%, rocket-propelled grenades 15% and 14% other. The hands (80% of patients) and the face (77%) were the most frequently burned body areas. Burns were isolated to the hands in 6% of patients and to the face and hands in 15%. An average of 52 ± 30% of the surface area of the hands and 45 ± 26% of the face was burned. Mean length of stay was 24 ± 25 days (median 14). Though 77% of patients were discharged without global disability, only 36% returned to full military duty. A similar pattern of injury and disposition was seen at the Army burn center in Vietnam (1966–1968), but mortality was higher (7.9%).

Conclusion: Burns resulting from combat explosions increased in frequency, size and injury severity. Burns were concentrated on areas not protected by clothing or equipment. These injuries created long hospital stays and frequently prevented soldiers from returning to duty. While wound distribution has not changed, combat burn care has improved, and continued emphasis on military protective equipment for the hands and face is warranted.

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Keywords: Burns; Military trauma; Epidemiology; Prevention

1. Introduction

Burns are a significant source of battlefield injury, historically accounting for between 5 and 20% of combat casualties in conventional warfare [1,2]. Since World War II severe burns have consistently accounted for approximately 4% of overall combat mortality [3]. The detonation of explosive devices such as landmines, artillery munitions, and mortar rounds has been a significant source of combat injury for U.S. forces, making a significant contribution to the number of burns sustained by military personnel as the result of hostile action in areas of combat operations [4,5].

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Due to the frequent use of explosive devices by enemy agents against personnel in Operations Iraqi and Enduring Freedom (OIF and OEF) in Iraq and Afghanistan, burns continue to comprise a significant percentage of combat wounds resulting from ongoing military operations. Currently, casualties with burn as their primary wound account for approximately 5% of those evacuated from the theaters of operation in Iraq and Afghanistan. The causes of explosions resulting in burns from the current conflicts are novel, with many injuries resulting from improvised devices rather than conventional munitions. The pattern, characteristics, and severity of the wounds caused by such devices are not well defined.

We undertook the current study in order to analyze the pattern and severity of burns incurred by military forces in OIF and OEF as the result of detonations of explosive devices in combat. It was our intention to use the data gathered for two purposes. The first goal was to examine the impact of these burns on military operational readiness. The second was to generate recommendations regarding potential measures that could be taken to reduce the incidence and severity of combat-associated burns occurring as the result of any hostile action throughout the world.

2. Methods

All casualties with significant burns sustained during OIF and OEF are evacuated by air and cared for at the burn center at the United States Army Institute of Surgical Research (USAISR) in San Antonio, Texas. The USAISR burn center prospectively maintains databases containing information on the pattern, severity, care, and outcome of the burn injuries of military and civilian patients. Following approval from the Brooke Army Medical Center/USAISR institutional review board, a retrospective review of data from existing institutional databases was performed. The first OIF or OEF patient was admitted to the USAISR on 5 April 2003. Data was acquired for patients admitted during the period beginning on this date and ending on 23 April 2005.

The USAISR patient census database contains demographic information on the military status and nature of injury for all civilian and military patients treated at the Institute. The trauma registry database contains information regarding the pattern of burn, overall injury severity, and early patient outcomes. These databases were used to compile the patients from OIF and OEF who sustained burns as the result of the detonation of enemy explosive devices and munitions. Demographic information, the causes, pattern, severity, and characteristics of burn, and early patient outcomes were recorded. A study database was created using Excel (Microsoft, Redmond, WA), and descriptive statistics were performed on all data using this program. Data are presented as mean ± standard deviation with medians and ranges in parentheses. Frequency distributions were also examined for selected variables.

Data were available only for those patients treated at the USAISR burn center. Individuals with burns who died in the field or during evacuation and those who were treated at other facilities were not included; however, the USAISR is the only United States military center for burn care. Data were also unavailable for patients returned to duty without evacuation following treatment for small, superficial burns.

3. Results

3.1. Demographics

There were a total of 274 patients from OIF and OEF admitted to the USAISR during the inclusion period. Of these, 142 (52%) sustained burns as the result of the detonation of an explosive device through the action of hostile agents. The rate of patient admission for explosive burns and the proportion of patients sustaining these injuries have increased over the course of the conflict (Table 1). In addition to the increasing incidence, severity of burn injury has increased with mean total body surface area (TBSA) burned decreasing between 2003 and 2004, but increasing to its highest level in 2005. Injury severity scores (ISS) and frequency of inhalation injury (as diagnosed by fiber optic bronchoscopy) increased consistently from 2003 to 2005. The mean age of patients burned in combat explosions was 26 ± 7 years (median 24, range 18–48). The majority of the burns were small and the patients had accordingly low injury severity scores (Fig. 1). The mean burn size among the 142 explosion burn casualties was 15.6 ± 18.3% TBSA (median 8.2, range 0.5–95). Mean overall ISS was 12 ± 14 (median 6, range 1–75).

Table 1
Mean burn size, injury severity score, and frequency of upper airway burns among casualties burned in explosions resulting from enemy action during ongoing conflicts in Iraq and Afghanistan

	Patients (%)	Rate	% TBSA	ISS	Upper airway (%)
5 April–31 December 2003	16 (18)	1.8	15.1 ± 12.3	8 ± 11	6.3
1 January–31 December 2004	84 (68)	7.0	13.0 ± 15.8	10 ± 12	7.1
1 January–23 April 2005	42 (69)	10.5	19.5 ± 23.6	15 ± 17.0	26
Entire population	142 (52)	5.7	15.6 ± 18.3	12 ± 14	13

Data are presented mean ± standard deviation. Percentages in parentheses represent the fraction of the total OIF and OEF patient load accounted for by burns resulting from explosions in combat. Rate of admissions is expressed as patients per month. The rate of admissions has increased over time, as has overall burn size and severity. TBSA, total body surface area; ISS, injury severity score.

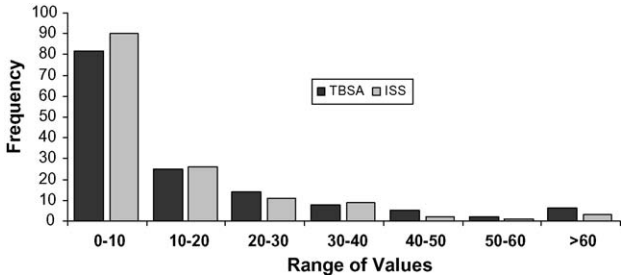

Fig. 1. Frequency distribution of TBSA burned and ISS among casualties burned in explosions resulting from enemy action during ongoing conflicts in Iraq and Afghanistan. The majority of the burns were small in size and patients had correspondingly low ISS. TBSA, total body surface area; ISS, injury severity score.

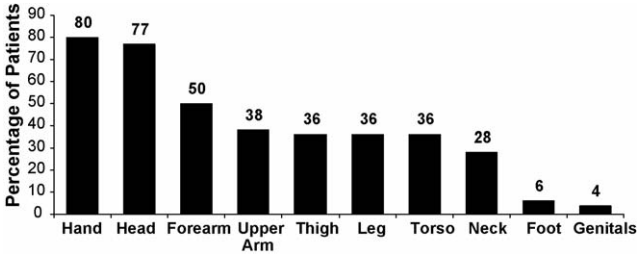

Fig. 3. Pattern of burn injury among casualties burned in explosions resulting from enemy action during ongoing conflicts in Iraq and Afghanistan. Actual percentages appear above the bars. The hands and the head are the body areas with the greatest frequency of burn injury. Areas covered by uniforms and personal protective equipment sustained relatively fewer burn injuries.

The detonation of improvised explosives and conventional munitions devices was the cause of nearly all of the explosive burns sustained during OIF and OEF operations. Many personnel were injured while driving or riding in military vehicles. Burns incurred as the result of the detonation of makeshift munitions such as improvised explosive devices and vehicle-borne improvised devices (car bombs) accounted for over 70% of the burn injuries. Standard conventional munitions such as mortars, rocket-propelled grenades, and landmines accounted for nearly all of the remainder (Fig. 2).

3.2. Injury pattern

The hands and head were the body areas most frequently burned in this population (Fig. 3). Eighty percent of burn casualties sustained burns to the hand, and more than three quarters sustained burns to the head, primarily affecting the face. The forearm was involved in half of the casualties, while the upper arm, torso, lower extremities, and neck were relatively spared. Twenty-one (15%) of casualties had burns isolated to the hands and the head and 8 (6%) had hand burns alone. The thigh (7.4%), torso (7.3%), and leg (5.9%), though not the most frequently burned body areas, were the body areas contributing the most to the overall TBSA burned. The hand, forearm, and neck had burns involving over half of their at-risk surface area and the head sustained burns over 40% of its at-risk area (Fig. 4).

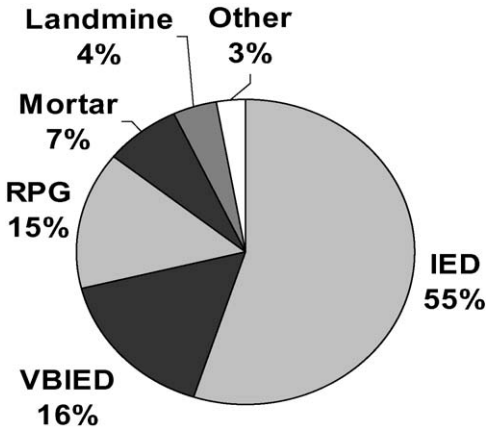

Fig. 2. Cause of burn injury among casualties burned in explosions resulting from enemy action during ongoing conflicts in Iraq and Afghanistan. Detonation of improvised devices caused the majority of burn injuries, while conventional munitions were less common. IED, improvised explosive device; VBIED, vehicle-borne IED; RPG, rocket-propelled grenade.

3.3. Outcomes

At the time of writing, 17 of the 142 casualties (12%) remained inpatients at the USAISR and their data are not included in the analysis of outcomes. Of the remaining 125 patients, 5 died for an overall mortality rate of 4.0%. The mean length of stay at the USAISR among the 120 survivors was 24 ± 25 days (median 14, range 2–154). Those patients with burns isolated to the head and/or hands had a mean inpatient stay of 9 ± 7 days (median 6, range 2–29) and those with burns isolated to the hands stayed 8 ± 6 days (median 6, range 2–16). Of the 125 surviving patients 114 (91%) were discharged to their own or their families' care, with only 4 patients requiring inpatient care following discharge from the burn center. Two patients were transferred to other inpatient services following their stay at the burn center.

Forty-five (36%) of the 125 patients with dispositions were returned to military duty without specified limitations

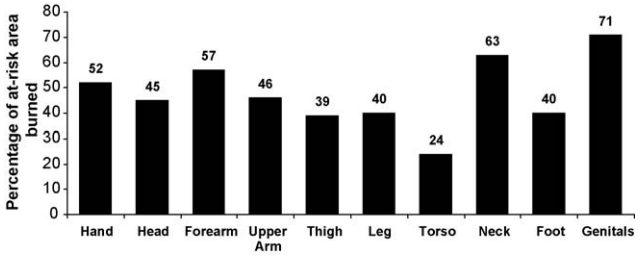

Fig. 4. Percentage of at-risk surface area burned by body area among casualties burned in explosions resulting from enemy action during ongoing conflicts in Iraq and Afghanistan. The most frequently burned body areas, the hand and head were each burned over 40% of their at-risk surface area.

while 13 (10%) were returned to their military units with duty limitations as a result of their injuries. Twenty-six patients (21%) were released from military service because of their injuries, and 35 (28%) are pending decisions regarding their ability to continue serving in the armed forces. Overall assessments of functional recovery were generally good, with 109 (87%) discharged at their previous level of global functioning, 8 (6.4%) discharged with moderate disability but able to care for themselves, and only three discharged with severe disability, unable to provide self-care.

4. Discussion

The problem of burns in the ongoing conflicts in Iraq and Afghanistan is a significant one. This report documents the problem as it relates to burns occurring as the result of hostile action comprising the use of explosive devices of varying kinds. Such detonations account for just over one half of all burns from OIF and OEF. We have also reported on our overall experience with OIF and OEF burns over the same time period [13]. To place the injuries documented in the current report in context, among 273 total OIF and OEF burn patients seen at the USAISR from March 2003 to May 2005, 62% were wounded as the direct result of hostile action with the majority of these injured in explosions. The remainder of burns did not result from enemy action. To comprehensively define the epidemiology of burns in current operations, a complete data set including those patients who were not admitted to the USAISR Burn Center would be needed. Unfortunately, such data are not available at this time, and so these casualties are not reflected in this report.

On the modern battlefield, burn injuries continue to represent a significant source of combat-related mortality and morbidity. This is especially apparent in ongoing conflicts because of the nature of operations in the Iraqi and Afghan theaters. These missions frequently involve ground operations consisting of foot patrols or ground watches and vehicle-based operations on an urban battlefield. During such operations, military personnel are subject to unpredictable attack by improvised and conventional incendiary explosive devices. The predominance of the detonation of improvised devices as a cause of combat burn injury presents challenges in the care of combat casualties. The devices causing burns span a range from small, homemade bombs filled with ball-bearings or other shrapnel-producing agents to modified conventional incendiary munitions such as large charge-filled howitzer rounds to fuel tanks with detonators. The array of devices used and thus the injury pattern created by them has been previously unseen on a large scale by U.S. forces. Regardless of the device used, combat explosions may result in burns through two mechanisms; directly from the heat of the initial explosive blast or from the secondary effect of burning vehicles, clothing, and equipment. The frequency and severity of burn is increasing, along with the proportion of patients who are injures in combat explosive detonations.

Many of the personnel injured in OIF and OEF explosions sustained burns when a vehicle in which they were riding came under attack by an explosive device. Burns incurred during battlefield vehicle operations arise from two primary sources: the explosion of armament on or near the vehicle and the fires that result from the combustion of ammunition, fuel, or hydraulic and other flammable fluids [6]. This dual nature of the etiology of vehicle-associated burns in combat partially explains the pattern of injury seen in our population. Those with small burns isolated to the hands and head likely suffered their burns during the initial explosion while their arms and faces were exposed outside the vehicle when it was attacked by a detonating device. Those with involvement of the trunk and lower extremity tended to have larger surface area burns and likely were burned by fires occurring in smoldering vehicles, a phenomenon similar to that seen in burn casualties during the Vietnam War [4].

In this population of casualties with burns sustained as the result of the detonation of hostile explosive devices, the mean burn size was small and 75% of patients had involvement of less than 20% of the TBSA. This distribution mirrors those seen in historical conflicts where the approximately 80% of burns involve less than 20% TBSA [1]. 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 [4,7].

The small average size of the burns seen in this population belies the morbidity carried by these injuries. Burns to the hands and face are some of the most difficult to care for, and can have significant long-term morbidity and functional consequences [8–10]. The predominance of burn injury of the hands and head (particularly the face) is a pattern that has been identified throughout recent military history. During the Lebanese war of 1982, over three-quarters of burn casualties with unprotected hands and face suffered burns to these areas [7]. In the Vietnam War, Allen et al, working at an in-theater burn center in Japan with a similar relationship to the combat field hospitals as the USAISR, identified that a significant portion of the burn casualties had small flash burns to the hands and face and that these injuries posed treatment challenges out of proportion to their total burn size [4]. While the mean length of hospital stay among patients with head and hand burns from explosions in OIF and OEF was short, all of these patients required periods of outpatient rehabilitation at the USAISR following discharge and prior to decisions being made regarding their eventual military disposition.

The overall mortality rate of 4% in this population is lower than the figure of 7.9% noted by Allen et al, likely reflecting improvements in critical care and early excision of burn wounds for patients with the most severe injuries [4]. Even though global assessments of functional outcome at the

time of hospital discharge were favorable, with most patients able to care for themselves, many patients were unable to return to full military duty in their pre-injury roles. One-fifth of patients were discharged from military service entirely, and over a quarter of patients still pending a decision regarding their future in the armed forces due to ongoing rehabilitative and reconstructive needs. The even temporary removal of personnel from military service can place significant strain on the readiness level of military units who now must replace an experienced member of their organization or must maintain readiness despite depleted personnel resources.

An additional 10% of personnel were returned to their military units with medical limitations placed upon the duties that they can perform. Those service members who return to duty with medical limitations may not be able to perform their original functions, and this can also limit a unit's operational effectiveness. An example seen with some frequency in this population is the infantry soldier who has sustained isolated burns to the hands and is unable to fire a weapon properly. The soldier in this situation will require retraining and reclassification into a military occupation that he can perform with his limitations and his injuries will affect the readiness of the military unit. Even the units who had personnel returned to full duty without limitations will have felt the impact of losing the service members for the period of time including their evacuation, inpatient treatment, outpatient treatment, and return.

Many patients in this population sustained burns isolated to areas of the body that were unprotected by military clothing and equipment. The high incidence, great morbidity, and potential preventability of burns to the hands and head in combat situations have been identified in the past, and wider and more consistent use of protective garments has been advocated [11]. The protective effects of conventional and specialized clothing and equipment in combat burn injury have been well documented. Fire-retardant flight suits made of Nomex, when properly worn, reduce the incidence and severity of burns associated with military helicopter accidents [12]. Similar suits were issued to tank and armored vehicle crewmen in the United States Army beginning in 1970 and have demonstrated similar efficacy in combat operations, decreasing the severity of burn injury when such vehicles are attacked [6]. The best evidence of the efficacy of fireproof garments in armored vehicle combat is Israeli data from the 1982 war in Lebanon. In this conflict, the use of flame-retardant gloves alone reduced the incidence of hand burns from 75 to 7% among tank crewmen who sustained burns. The incidence of hand burns with glove use decreased from 25 to 2.5% among all injured crewmen [7].

The only reliable way to reduce the impact of explosive burns on military operational readiness is to prevent the injuries themselves. As has been seen in previously reported combat casualty populations, the distribution of burns seen in this population likely represents the protective effect of the wounded patients' clothing and equipment such as body armor. Many burns were isolated to the hands and head, indicating that protecting these areas from burn injury through the broader use of protective garments or devices could significantly reduce the total number of burns in this population. The use of protective garments on the hands and head/face alone might result in not only a reduction in the overall number of burn casualties, but also in decreased burn severity, morbidity, and potentially increased return-to-duty rates among soldiers that are burned.

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