Burn Hazards of the Deployed Environment in Wartime: Epidemiology of Noncombat Burns from Ongoing United States Military Operations

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BACKGROUND: Service in the deployed military environment carries risks for accidental (noncombat-related) burns. Examining these risks can assist in the development of military burn prevention measures. This study endeavored to examine noncombat burn epidemiology in the context of similar civilian data.

STUDY DESIGN: We performed a retrospective cohort study of consecutive casualties evacuated from operational military theaters in Iraq and Afghanistan to the sole tertiary military burn center in the US. Military data were compared with database samples of the US population from the American Burn Association and the Centers for Disease Control and Prevention.

RESULTS: The main causes of the 180 noncombat burns seen from March 2003 to June 2008 were waste burning, fuel mishaps, and unintentional ordinance detonations. Overall prevalence of noncombat burns was 19.5 burns/100,000 person-years lived. If causes specific to military operations are removed, military prevalence was 13.0/100,000. More than one-third of noncombat burns occurred in the first year of the study; a period of stability followed. A similar US population had an accidental burn prevalence of 7.1/100,000 from 2003 to 2007. Burn size, presence of inhalation injury, and burn center mortality were not different from those in a similar civilian cohort.

CONCLUSIONS: Deployed service members have a greater risk of unintentional burns than a similar civilian cohort does. This is in part because of the specific dangers of military activities. More attention to deployed military burn prevention is needed, especially early in combat support operations. (J Am Coll Surg 2009;209:453–460. © 2009 by the American College of Surgeons)

During the last century and a half, US military operations have produced hundreds of thousands of casualties. These casualties can be grouped into those resulting from hostile activity (combat or battle injuries and deaths) and those resulting from nonbattle injury (noncombat casualties).[1] A combat zone is by its nature a dangerous place, and although many of the dangers are inherent to the task at hand—fighting in armed conflict—others are related to the deployed military environment itself. Historically, nonbattle casualties have accounted for a varying amount of wartime mortality, but the contribution has always been significant (Table 1).

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The opinions and/or assertions contained herein are solely those of the authors and should not be construed as reflecting those of the US Army, Department of Defense, or government.

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Burns are encountered in a small but significant proportion of both combat and noncombat casualties in modern warfare. In the 20th and 21st centuries, this proportion has been between 5% and 20% of all casualties.[2-4] During the Vietnam War, more than one-half of evacuated burn casualties were burned outside of circumstances resulting from enemy activity, and initial reports from the ongoing conflicts in Iraq (Operation Iraqi Freedom [OIF]) and Afghanistan (Operation Enduring Freedom [OEF]) have revealed that more than one-third of burns are classified as noncombat injuries.[5,6]

Austere environmental conditions and the work related to supporting combat operations pose burn risks but are necessary components of prosecuting and sustaining armed conflict. Waste burning, handling of ammunition, and fueling vehicles and generators, among others, are activities that have been identified as posing burn risks in OIF and OEF, and some efforts have been made to mitigate these.[6,7] This study was devised to describe the epidemiology of the noncombat burn hazards that exist in OIF and OEF by examining data from burn casualties evacuated to

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Abbreviations and Acronyms

LOS = length of stay
OEF = Operation Enduring Freedom
OIF = Operation Iraqi Freedom
TBSA = total body surface area
USAISR = US Army Institute of Surgical Research

the US Army Institute of Surgical Research (USAISR) burn center in San Antonio, TX, from the theaters of operations in Southwest Asia. We aimed to characterize deployed military burn risks in the context of those seen in the US' civilian population in order to determine if and in what way the deployed military environment was more or less dangerous than the civilian environment vis-à-vis unintentional burns.

With such epidemiologic data, we hoped to be able to provide evidence-based recommendations for the prevention of further noncombat burns among deployed service members. The USAISR facility is the sole US military burn referral center and, as such, receives all significant burn casualties evacuated from the combat zone. So it is uniquely suited to performing epidemiologic research on US military burn casualties.

METHODS

This retrospective study received approval from the Brooke Army Medical Center Institutional Review Board. The records of all active-duty military patients evacuated from OIF and OEF to the USAISR were reviewed. Data collection began with the initial evacuations of burn casualties occurring in March 2003, and collection ceased with patients injured in June 2008, covering a period of 64 months. All patients had been burned in either the Iraq or Afghanistan theater and received initial resuscitation and topical treatment there, although no definitive or surgical burn care was provided for any patient until arrival at USAISR. Casualties were evacuated by air through a staged system of progressively increasing patient care capability, from combat hospitals in Iraq and Afghanistan, through the military regional medical center in Landstuhl, Germany, and finally to the USAISR. In cases of severe burns or critically ill burned patients, the USAISR Burn Flight Team, consisting of specially trained and equipped burn physicians, nurses, respiratory therapists, and support staff, evacuated the patient from Germany to the USAISR.[8] The decision to evacuate a patient to the USAISR burn center was made based on the burn center transfer criteria of the American Burn Association,[9] ensuring that all patients with significant burns or with significant traumatic comorbidities along with their burns were sent to the USAISR burn center. Duration of evacuation was calculated as the number of days between the date of wounding and the date of burn center admission.

Upon admission to the burn center, the circumstances under which injury occurred were garnered from transfer medical records and from conversation with the patient, if possible. This information was made part of the inpatient electronic medical record. For the purposes of this study, patient demographic data and information pertaining to the wounding event and its circumstances were extracted from the inpatient medical records of all evacuated casualties. These data were reviewed for the study and were then placed into an electronic database. Injury mechanisms were categorized by the specific weapon used in the wounding incident or the noncombat cause of the burn injury. From the available information, a determination was made by the principal investigator (DSK) as to whether the injury was the result of enemy activity (combat-related) or was not related to enemy activity (noncombat injury).

The admitting burn surgeon determined the pattern and depth of burns upon burn center admission using the method described by Lund and Browder.[10] All patients with any suspicion of inhalation injury (oxygen requirement, facial burns) and all intubated patients had this diagnosis confirmed or excluded with fiberoptic bronchoscopy shortly after admission. All nonburn injuries were diagnosed on admission with physical examination and radiologic imaging as appropriate, and Injury Severity Scores (ISS) were calculated for all patients.

Table 1. Total and Nonbattle Deaths from Major US Armed Conflicts

Conflict	Years	Total deaths, n	Nonbattle deaths, n	Nonbattle, %
Civil War (Union)	1861–1865	364,511	224,097	61
World War I	1917–1918	116,516	63,114	54
World War II	1941–1946	405,399	113,842	28
Vietnam	1964–1973	58,209	10,785	19
Desert Shield/Storm	1990–1991	382	235	62
OIF/OEF (through March 2008)	2001–present	4,492	933	21

Data abstracted from a congressional research service report.[1]
OIF/OEF, Operation Iraqi Freedom/Operation Enduring Freedom.

Mortality was defined as death from any cause occurring during the patient's initial hospitalization. Inpatient complications were tabulated as a categorical variable, and any complication during the initial hospitalization was considered a "positive" result. Hospital length of stay (LOS) was defined as the number of days from burn center admission to the initial disposition, whether it be to home or to another inpatient or rehabilitation facility. The LOS of patients who died during their initial hospitalization was not considered in calculating group LOS.

Civilian burn data from the US was extracted from the Web-based Injury Statistics Query and Reporting System database available from the Centers for Disease Control and Prevention[11] and from data published by the American Burn Association in its annual multiinstitutional report.[12] The inpatient mortality and complication data garnered from the American Burn Association database are for civilian burn patients only, a population similar to our military burn center population. The nationwide incidence data for civilians from the Centers for Disease Control and Prevention were censored to include only civilian burn patients who were admitted to the hospital or transferred to another hospital for care, or both. This censoring was done in an attempt to make the military and civilian populations as comparable as possible.

Estimated in-theater troop strength data compiled by a private third party (the government does not routinely release numbers of deployed service members) were used to provide an estimate of the relative population at risk for noncombat injury during the period of time covered by our review. Estimated troop strength data were retrieved from reports on the Web.[13] These data were collated and entered into the study database.

Descriptive data are presented as means ± standard deviations, with medians and ranges as appropriate. Direct comparisons between population means were performed with *t*-tests for continuous data and chi-square or Fisher's exact tests as appropriate for proportions. Statistical significance was defined as a p value less than 0.05.

RESULTS

From March 2003 to June 2008, a total of 711 casualties from OIF and OEF were admitted to the USAISR burn center. Of these, 13 had no burns and were excluded from the study. Of the remaining 698, an additional 10 had insufficient information in their records regarding the circumstances under which they were injured such that no determination could be made about the combat or noncombat status of their wounding. These were also excluded from analysis. The remaining 688 burn casualties formed the study population. Military patients were young, with a mean age of 26 years (range, 18 to 52 years), and 667 (97%) were men. Of the 688 casualties, 508 (74%) were burned in combat, leaving a noncombat burn population of 180 (26%).

Table 2. Comparison of Battle and Nonbattle Burn Casualties

Variable	Noncombat (n = 180)	Combat (n = 508)	p Value
Total body surface area	11 ± 13	19 ± 21	< 0.0001
Full-thickness total body surface area	5 ± 11	13 ± 21	< 0.0001
Inhalation injury	11 (6)	97 (19)	< 0.0001
Nonburn injury	20 (11)	272 (54)	< 0.0001
Injury Severity Score	6 ± 8	15 ± 15	< 0.0001
Length of stay	17 ± 24	30 ± 50	< 0.0001
Patients with complications	44 (24)	208 (41)	< 0.0001
Mortality	2 (1)	41 (8)	0.0009

Data are reported as mean ± SD or n (%).

The noncombat injured population differed from those injured in combat in a number of critical areas (Table 2). Both total body surface area (TBSA) burned and full-thickness TBSA burned were smaller among the noncombat injured, as were the incidences of inhalation and associated nonburn injuries. Correspondingly, the Injury Severity Score was lower in the noncombat burn casualties. As might be expected, given the less severe injury profile among noncombat-injured casualties, LOS was shorter and the rates of mortality and inpatient complications were lower in this population.

Only 2 deaths occurred among the 180 noncombat casualties, for an inpatient mortality rate of 1.1%. This rate was comparable to the 2.1% rate (236 of 11,338) reported by the American Burn Association for patients aged 20 to 30 years admitted to US burn centers in 2007 ($p = 0.59$, Fisher's exact test). The rate of inpatient complications was comparable among these 2 groups as well, at 24% for noncombat casualties and 25% for civilians ($p = 0.87$), as was the rate of inhalation injury, at 6% for noncombat casualties and 4% for civilians ($p = 0.16$).[12]

The etiologies of the 180 noncombat burns were varied. The largest contributor to this population was incidents involving the burning of refuse (24%). Other major contributors were incidents with fueling vehicles or generators (18%) and those involving the handling of ammunition or gunpowder (17%) or of flares and grenades (16%). Purely electrical burns (8%), other incidents with generators and radiators (6%), scalds (3%), and other causes (9%) accounted for the remainder of the noncombat casualties. Other causes included motor vehicle and helicopter crashes (four patients each), barbequing incidents (two patients), unexploded ordinance detonations (two patients), and single patients each with burns resulting from Freon spray,

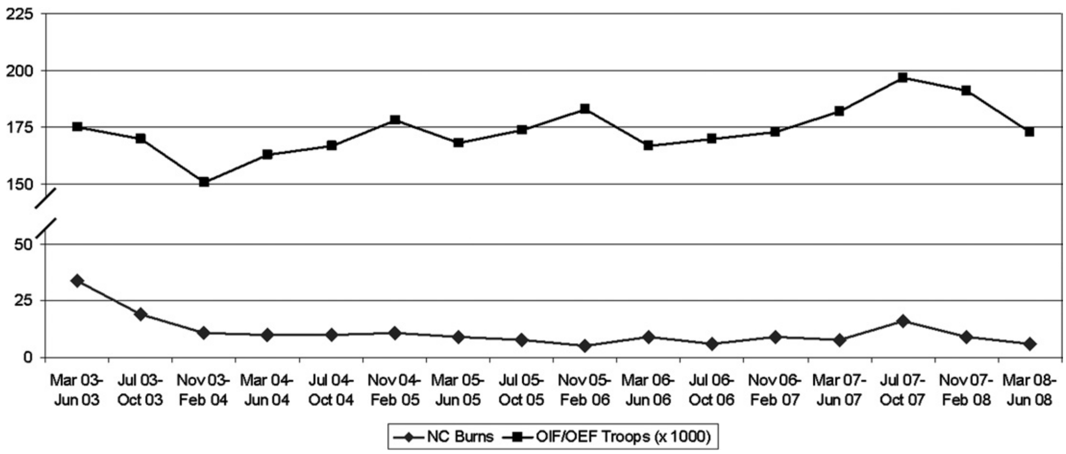

Figure 1. Incidence of noncombat burns and total/100,000 deployed troop strength for Operation Iraqi Freedom and Operation Enduring Freedom (OIF/OEF Troops) for 16 periods of 4 months each, from March 2003 to June 2008. Y-axis breaks between 50 and 150.

welding, refilling a cigarette lighter, and a vehicle fire not resulting from a crash.

Review of national burn center data compiled by the American Burn Association in 2007 revealed a large disparity between the mechanisms of military noncombat and civilian burns. If all of the noncombat military mechanisms resulting in burns by fire or flame (waste burning; barbequing; explosions of ammunition, gunpowder, and armaments; fueling; vehicle crashes; or fire) are considered together, as they are for civilians by the American Burn Association, the resulting rate of fire or flame injuries is 85% of noncombat burn injuries. By contrast, flame or fire accounts for only 44.5% of all civilian burn center admissions among patients aged 20 to 30 years. Some noncombat burns had causes that were "military specific," such as the handling of ammunition or gunpowder and the unintentional detonation of flares, grenades, or unexploded ordinance. If we remove these fire and flame hazards from the noncombat burn population, the fire and flame proportion becomes 56% and more closely approximates the civilian proportion of such injuries. The same dataset demonstrates that among those US civilians burned, scalds were more common than in the noncombat military population, accounting for 22.9% of burn center admissions, but electrical injuries were less common at 5.2%.[12]

There were an estimated monthly average of 173,742 service members deployed with OIF and OEF during the 64 months (5.3 years) from March 2003 to June 2008.[13] This were an estimated total of 920,833 person-years lived in the theaters of operations during this time period. So, the noncombat burn prevalence for OIF and OEF was 180 in 920,833, or 19.5 burns/100,000 person-years lived in the theaters of operations. The "military-specific" mechanisms of burns discussed above (ammunition handling and flare or grenade detonations) accounted for a total of 60 (33%) of the noncombat burn casualties. If these are removed from the above calculation, the prevalence of noncombat burns becomes 120 in 920,833 or 13.0 burns/100,000 person-years. The Centers for Disease Control and Prevention reports that from 2003 to 2007 among US civilian men between the ages of 18 and 52 years, the annual prevalence of hospitalization or transfer for unintentional burn injury was 7.1/100,000.[11] So from March 2003 to June 2008, a deployed service member in OIF or OEF had a 2 to 3-fold greater chance of unintentional burn injury than a similarly aged male US population cohort.

The incidence of noncombat burns over time was calculated for each of the 16 intervals of 4 months each comprising the period of the review. Incidence was calculated as the total number of burn casualties admitted per 4-month period and ranged from a high of 34 in March 2003 to June 2003 to a low of 5 for November 2005 to February 2006. Incidence was initially high in the early stages of OIF and OEF but tapered over the first year of the conflict and remained relatively constant for the remainder of the study period, even as the number of deployed service members fluctuated. An exception was in mid-2007, when approximately 21,000 additional US service members were added to forces in Iraq as part of the "surge" operation. During this time, the incidence of noncombat burns increased along with the number of troops in theater (Fig. 1).

The incidence of noncombat burn injury in the context of the estimated at-risk population over time was examined by dividing the total number of noncombat burn casualties by the estimated average number of service members deployed in OIF and OEF during each 4-month period. The results are expressed as noncombat burns/100,000 service

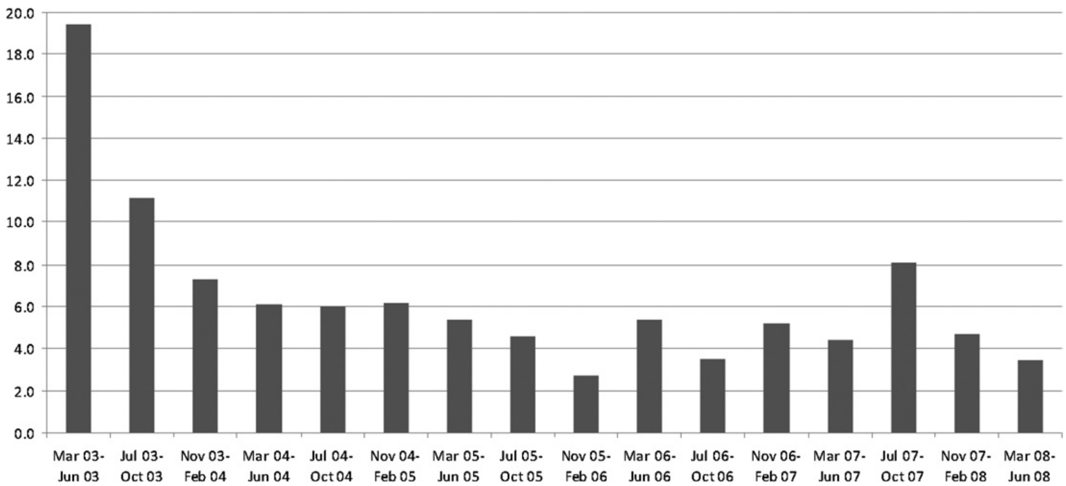

Figure 2. Noncombat burns/100,000 troops at risk for 16 periods of 4-months each, from March 2003 to June 2008.

members at risk for each 4-month period. Four-month incidence ranged from a high of 19.4/100,000 from March 2003 to June 2003 to a low of 2.7/100,000 from November 2005 to February 2006. Prevalence also increased during mid-2007 as additional forces were sent to Iraq (Fig. 2).

Mean burn size among noncombat casualties was 11 ± 13% TBSA, and the figure was heavily skewed toward smaller burns, with a median of 7% (interquartile range, 3% to 78%) TBSA. Eighty-four percent of noncombat casualties had 20% TBSA or smaller burns, and 62% had burns of 10% TBSA or smaller. This is a similar distribution to that seen in civilian burn centers in 2007, where 89% of patients had burns of less than 20% TBSA ($p = 0.33$), and 69% were burned over less than 10% TBSA ($p = 0.33$).[12]

In our military population, the hands were the most frequently burned body area, involved in 120 (67%) casualties. The forearm was burned in 92 (51%) and the face in 86 (48%) (Fig. 3). Eighteen (10%) noncombat casualties were burned solely on the hands. Six of these sustained electrical burns, four were burned by the unintentional discharge of flares or grenades, three each by burning refuse and ammunition detonation, and two in fueling mishaps. Only two of the casualties with isolated hand burns had associated nonburn injuries. One patient who was injured while burning refuse sustained a unilateral tympanic membrane rupture and one of those who had an electrical burn had a partial amputation of his index finger.

DISCUSSION

Burns remain an important source of military casualties from current operations. As noted in previous conflicts, burns unrelated to hostile activity constitute a significant proportion of the total burn casualty burden, currently 26% for OIF and OEF. This is an improvement over the Vietnam conflict, in which an in-theater burn center reported a noncombat burn rate of 51%.[5] Although this improvement is encouraging, noncombat burns are by their nature potentially preventable, and there is room for further reduction. The primary goal of this article was to describe the epidemiology of noncombat burns in OIF and OEF in the context of US civilian burn risks in order to determine the relative burn hazards of the deployed military environment. Through this evaluation, we hoped to be able to provide recommendations for further noncombat burn prevention measures.

It is clear from our data that there are significant differences in the pattern of injury between burn casualties injured in combat and those injured in noncombat incidents. This finding reinforces initial casualty data examined ear-

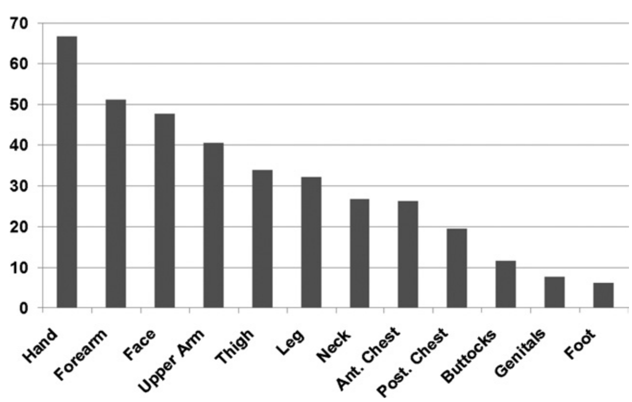

Figure 3. Anatomic distribution of burns in combat casualties by percentage of total casualties with specific area(s) involved.

lier in the current conflict.[6] Noncombat burn casualties are burned far less severely and have fewer associated traumatic injuries. Their outcomes are correspondingly better, with significantly lower mortality. These differences make these two populations distinct clinical entities, and in further study of military burns they should be examined independently. The specific reasons for the increased mortality rate among combat-wounded burn casualties require further study.

Our noncombat military casualty population was very young and overwhelmingly male, reflecting the demographics of the US armed forces in general. For this reason we attempted, when possible, to study our population in the context of a similar civilian population. Increasing age, burn size, and the presence of inhalation injury are the typical mortality predictors cited for burn patients,[14,15] and the military noncombat population had a similar distribution of burn size and rate of inhalation injury to similarly aged patients treated at US burn centers in 2007. So it is encouraging that our noncombat burn mortality was comparable to that of the civilian burn patient population.

Although mortality in the noncombat burn population was similar to that with civilian burns, the causes of burn injuries were not. Military noncombat burn patients were far more likely to be burned by fire or flame than their similarly aged civilian counterparts. This disparity in flame burn percentage appears to be principally the result of participation in hazardous activities related specifically to military operations in the combat zone. These activities include the handling of explosives, such as ammunition, flares, and grenades, all of which resulted in fire or flame burns in our noncombat population. The other causes of noncombat burns are similar to those seen in a civilian working-age population: burning of refuse, incidents involving misuse or mishaps with volatile fuels, incidents with generators, and motor vehicle and helicopter crashes.[16] The military-specific tasks noted are all associated with combat operations, and the incidence of burns resulting from mishaps occurring while performing these would be expected to increase along with the operational tempo. This is in fact what we noted, with an increase in noncombat burns during the "surge" of troops in mid-2007 into the Iraq theater of operations.

But the risk of burns from munitions is not limited to the deployed combat environment. In a 2001 report on noncombat munitions injuries in the US Army, Kopchinski and Lein[17] found 261 burns among 894 injured soldiers from munitions incidents over an 86-month period, which included Operations Desert Shield and Desert Storm. Burns were the most common mechanism of injury and were most commonly associated with combat training exercises, even those occurring outside of the combat theater. This indicates that some of the burn risk seen in the military population has to do with the inherent occupational risks of military activities and not necessarily with the deployed military environment itself. These data suggest that the noncombat burn risk in the military population may be somewhat mitigated by prevention efforts directed at the performance of high-risk military activities, such as explosives handling, in both the training and combat environments.

The prevalence of noncombat burn injury in OIF and OEF was 19.5 patients/100,000 person-years in the combat theater. This is much higher than the rate of 7.1 unintentional burns/100,000 per year seen in a US male population of similar age during a time period equivalent to that covered by our review. The prevalence differential could not be explained solely by the burns occurring in the performance of military-specific tasks, because the military incidence is 12.6/100,000, even after patients burned performing such tasks were removed. This suggests that there are burn hazards that are inherent to the military environment above and beyond those that occur because of some of the more dangerous activities performed in support of combat operations.

A clue to the reason for the increased prevalence of unintentional burns among service members in the deployed environment can come from examining the incidence of such burns over time. More than one-third of the OIF and OEF noncombat burn casualties (64 of 180) occurred in the first 12 months of our data collection period. If the initial 12 months of noncombat burn casualties are omitted from the data, representing those burns that occurred in the combat theater after the high incidence seen initially during the expeditionary phase of the OIF conflict, the prevalence decreases to 15.4 casualties/100,000 person-years. This more accurately reflects the "baseline" prevalence of noncombat burns in the mature combat theater. If all of the military-specific activity burns are removed from this calculation, then the prevalence decreases to 10.2 burn casualties/100,000 person-years in theater, which more closely approximates the civilian prevalence of 7.1 unintentional burns/100,000 person-years lived in the US among young men from 2003 to 2007.

During the initial phases of large military operations such as OIF and OEF, not only is there a high pace of combat operations with attendant increased burn risks as noted above, but service members also live and work in austere conditions, a situation that comes with its own burn hazards. The clearest of these is the hazards encountered during the incineration of refuse and human waste, which was the most frequent source of our noncombat burn casualties. Incineration is a standard military practice for waste disposal and has been identified as a contributor to unintentional burn morbidity in previous conflicts.[5] In OIF and OEF, the practice initially led to high numbers of noncombat burn casualties in OIF and OEF and drew attention from the burn care providers at the USAISR.[4] A prevention program was implemented in the combat theater and has been somewhat effective in mitigating this risk.[7]

As the OIF and OEF combat theater matured from 2003 to 2004, the pace of initial combat operations slowed, and more permanent facilities and procedures were acquired and constructed for sanitation and other burn-prone tasks. There was a corresponding decrease in the incidence of noncombat burns to between 2 and 6 per 100,000 troops in theater, which, after the initial high incidence, represented the "baseline" incidence for the theater of operations (Fig. 2). This fairly constant baseline of noncombat burns in the face of fluctuating levels of troops means that the theater had matured properly after the first year of operations. The observed increase in incidence to 8/100,000 at risk with the addition of about 21,000 "surge" troops in 2007 indicates that there is room for improvement in noncombat burn prevention. If the combat theater were truly at a baseline minimal risk determined by living and operating conditions, we would have expected the burn incidence to remain the same regardless of the additional troops in the theater. It is interesting to note that noncombat burn incidence decreased even as the "surge" troops remained in the theater. This is most likely from a combination of decreasing operational tempo (and associated combat-support tasks as noted earlier) and the evolution of the combat theater to provide a safer noncombat environment for the additional service members. Military commanders should expect a transient increase in noncombat burn casualties whenever a large number of troops are added to even a mature combat theater.

Noncombat burns sustained in the deployed military environment remain an important source of combat theater morbidity, and many of these injuries are potentially preventable. A high incidence of hand burns is universally reported from military operations,[5,18,19] and the incidence of burns to the hands has been found to be significantly higher among military burn patients from OIF and OEF than in the civilian burn population.[20] Wearing of gloves can be very effective in the prevention of burns to the hands in military operational situations, especially when they are worn during the performance of high-risk activities. In the 1982 Israeli war in Lebanon, the issuance of gloves to tank crewmen reduced the incidence of hand burns from 75% to 9% among those burned.[21] All service members deploying to OIF and OEF are issued gloves, yet 10% of our noncombat burn casualties received burns only to the hands. All of these hand-only injuries occurred during the performance of high-risk activities, suggesting that these 18 burns could have been completely prevented had the patients been wearing their gloves at the time of their injury. Hand burns are particularly morbid injuries,[22] and from our data we strongly advocate the wearing of gloves during high-risk activities and continued emphasis on this aspect of preventative medicine by military medical authorities.[23] The USAISR, as the sole US military burn center, has been heavily involved in advocacy and policy matters regarding the provision and use of flame-retardant garments and other equipment to prevent both combat and noncombat burns. Currently, all service members deploying in support of OIF and OEF are issued gloves and flame retardant uniforms before arrival in the combat theater. The real-world effectiveness of these should be the subject of further research into the epidemiology of military burn casualties.

We have demonstrated that service members deployed to the OIF and OEF theater military environment in support of combat operations have a baseline risk of burn injury that exceeds by a factor of two to three the risk faced by a similar population in the US. This increased risk appears to be somewhat mitigated by the specific requirements of their environment. Resources developed in a maturing combat theater seem to result in reduced noncombat burn risks. These include the development of centralized power plants to replace portable fueled generators and the use of chemical toilets or the development of sanitary sewer systems to eliminate waste burning. Such developments can further reduce the incidence of noncombat burn injury. Emphasis on safe procedures and the wearing of protective garments during high-risk, and especially military-specific, activities, such as handling explosives, generator fueling, and maintenance, and during vehicle-fueling activities, remains indicated in attempts to reduce the incidence and impact of noncombat military burn injuries.

Author Contributions

Study conception and design: Kauvar, Wade, Baer
Acquisition of data: Kauvar, Wade
Analysis and interpretation of data: Kauvar, Wade, Baer
Drafting of manuscript: Kauvar, Wade, Baer
Critical revision: Kauvar, Wade, Baer

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