Combat-Related Facial Burns: Analysis of Strategic Pitfalls

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Purpose: Burns constitute approximately 10% of all combat-related injuries to the head and neck region. We postulated that the combat environment presents unique challenges not commonly encountered among civilian injuries. The purpose of the present study was to determine the features commonly seen among combat facial burns that will result in therapeutic challenges and might contribute to undesired outcomes.

Materials and Methods: The present study was a retrospective study performed using a query of the Burn Registry at the US Army Institute of Surgical Research Burn Center for all active duty facial burn admissions from October 2001 to February 2011. The demographic data, total body surface area of the burn, facial region body surface area involvement, and dates of injury, first operation, and first facial operation were tabulated and compared. A subset analysis of severe facial burns, defined by a greater than 7% facial region body surface area, was performed with a thorough medical record review to determine the presence of associated injuries.

Results: Of all the military burn injuries, 67.1% (n = 558) involved the face. Of these, 81.3% (n = 454) were combat related. The combat facial burns had a mean total body surface area of 21.4% and a mean facial region body surface area of 3.2%. The interval from the date of the injury to the first operative encounter was 6.6 ± 0.8 days and was 19.8 ± 2.0 days to the first facial operation. A subset analysis of the severe facial burns revealed that the first facial operation and the definitive coverage operation was performed at 13.45 ± 2.6 days and 31.9 ± 4.1 days after the injury, respectively. The mortality rate for this subset of patients was 32% (n = 10), with a high rate of associated inhalational injuries (61%, n = 19), limb amputations (29%, n = 9), and facial allograft usage (48%, n = 15) and a mean facial autograft thickness of 10.5/1,000th in.

Conclusions: Combat-related facial burns present multiple challenges, which can contribute to suboptimal long-term outcomes. These challenges include prolonged transport to the burn center, delayed initial intervention and definitive coverage, and a lack of available high-quality color-matched donor skin. These gaps all highlight the need for novel anti-inflammatory and skin replacement strategies to more adequately address these unique combat-related obstacles.

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The incidence of burn injuries among those evacuated in the previous 10 years of the Overseas Contingency Operations was approximately 5%.[1] However, because these injuries were disproportionately distributed toward body areas not protected by armor, burns have accounted for 10% of combat-related injuries to the

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head and neck region.[2,3] Consequentially, facial involvement was present in 77% of all combat-related burn admissions.[4,5]

Devastating facial burns can have considerable cosmetic and psychological implications and can significantly affect a patient's functional recovery. Although one's identity is integrally bound to one's facial appearance, our basic senses and several essential functions (ie, vision, hearing, speech, deglutition, and respiration) can be compromised by burn scars.[6,7] The stigmata of facial burns includes lower eyelid ectropion, a short nose with alar flaring, a short and retruded upper lip, an everted lower lip with or without concomitant microstomia, flat facial features, various auricular deformities, a restricted neck extension, and a loss of jaw line definition.[8] Burn scars, developing after both full- and partial-thickness burns, can result in these deformities and contractures that persist far beyond their acute recovery and require multiple sequential reconstructive operations.[2]

Several studies have analyzed the characteristics of combat-related burns, although none have specifically focused on the face. In those studies, they noted both conventional and improvised explosive devices were the cause of these thermal injuries. Combat injuries result in greater burn depths, a greater incidence of inhalation injuries, a greater incidence of concomitant nonburn injuries, and a greater total injury severity score compared with a civilian cohort.[5,9,10] In the present study, the burns to the head and neck region incurred during the previous 10 years of conflict were queried to determine the injury pattern and operative characteristics that could pose therapeutic challenges. Thus, the gaps in our treatment can be identified and research directed toward areas of need.

Materials and Methods

A retrospective review was performed using the Department of Defense Trauma Registry and the US Army Institute of Surgical Research Burn Registry. The Department of Defense Trauma Registry is a database of all US service members injured and treated at a military treatment facility since the beginning of the wars in Iraq and Afghanistan. Both databases were queried from October 2001 to April 2011 for active duty subjects who had sustained a burn injury. These subjects' injuries were further divided into combat- and noncombat-related burns. The demographic data, total body surface area (TBSA) of the burn, and facial region body surface area (FBSA) involvement were tabulated. For the purpose of the present study, burn involvement to the head and neck body region was collectively referred to as the facial region. The Burn Registry and the surgical scheduling database were also queried for the dates of the initial injury and the first operative encounter. An intensive care unit stay longer than 6 days was used as a selection criterion to aid in the exclusion of patients with nonacute injuries. A thorough medical record review was completed for a subset of the patients with severe facial burns (>7% of FBSA). The mechanism, dates, and modalities of definitive facial coverage, associated proximal extremity amputations, allograft usage, inhalational injury, rate of facial autograft failure, number and types of early eyelid release procedures, rates of concomitant facial fractures, associated fungal infection, and mortality were tabulated.

The present study was conducted under a protocol reviewed and approved by the US Army Medical Research and Material Command Institutional Review Board and in accordance with the approved protocol. The study databases were maintained under data encryption in Access (Microsoft, Redmond, WA). Statistical analysis of all the results was completed using the chi-square test for all categorical data and the paired Student t test for continuous data. The cutoff for significance was $P < .05$.

Results

A total of 832 active duty subjects with burn injuries were treated at the US Army Institute of Surgical Research Burn Center from October 2001 to April 2011. Of these 832 patients, 558 (67.1%) had facial involvement. Of the injuries with facial involvement, 454 (81.3%) were combat related. Combat-related facial burns had an average TBSA of 21.4%, with an average FBSA of 3.2%. A positive correlation was seen between the average TBSA and FBSA percentages ($P = .0001$; Fig 1).

A subset analysis was performed of those with severe facial burns (FBSA >7%; n = 31), revealing an average TBSA of 42.9%. These patients had sustained injuries that were largely the result of improvised

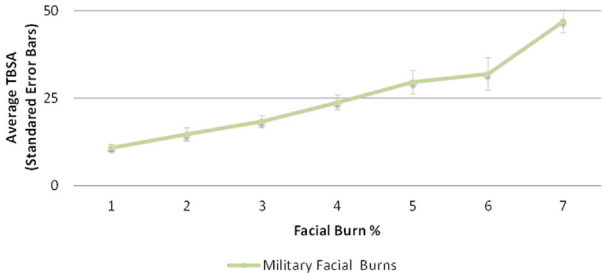

FIGURE 1. Graph of the mean total body surface area (TBSA) per percentage of facial body surface area involvement (FBSA) demonstrating a positive correlation between increases in FBSA and increases in TBSA.

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explosive devices and had an overall mortality rate of 32% (n = 10). Of the 31 patients, 4 (13%) were later found to have an invasive mucormycosis infection, and all of these infections were fatal, despite aggressive surgical and medical management. Also, 9 patients (29%) had associated extremity amputations; 6 (19%) involved the lower extremities (2 [6%] were proximal [above-the-knee] and 5 [16%] were distal [below-the-knee]) and 5 (16%) the upper extremities (4 [13%] were proximal [above-the-elbow] and 1 [3%] was distal [below-the-elbow]). In addition, 19 (61%) had an associated inhalational injury, of which, 7 were mild, 6 were moderate, and 6 were severe. Of the 31 patients, 6 (19%) had concomitant facial fractures, including 3 basilar skull fractures, 2 orbit fractures, 1 comminuted mandible with a condylar fracture, 2 zygomaticomaxillary complex fractures, 3 nasal fractures, 2 Le Fort I fractures, and 1 dentoalveolar fracture. Most patients (81% [n = 25]) had sustained some component of a full-thickness facial burn, and 48% (n = 15) required allograft application. Of the 31 patients, 7 (23%) underwent application of other skin substitutes such as Integra (Integra LifeSciences, Plainsboro, NJ) or AlloDerm (LifeCell, Bridgewater, NJ) to the face. The mean thickness of the definitive skin autograft was 10.5/1,000th of 1 in, with a mode of 10/1,000th of 1 in. The autografts were harvested from the scalp in 5 (33%), from the back in 5 (33%), and from the chest in 8 (53%). However, 16 of the subjects (52%) had documentation of graft failure for some portion of the graft that required repeat grafting. Moreover, 16 patients (52%) required some form of early eyelid ectropion release (Table 1).

MECHANISM OF INJURY

The mechanisms leading to combat-related facial burns were improvised explosive devices in 18 (58%), vehicle fires in 4 (13%), and attacks by rocket propelled grenades in 2 (6%). Individual cases of a car bomb and helicopter crash were documented, as were other mechanisms, such as explosions in 3 (10%), flash burns from fuel ignition in 2 (6%), and an electrical transformer burn in 1 (3%).

Table 1. CHARACTERIZATION OF SEVERE FACIAL BURN INJURED SUBJECTS (N = 31)

Characteristic	n (%)
Mortality	10 (32)
Amputations	9 (29)
Inhalational injuries	19 (61)
Facial allograft use	15 (48)
Facial allograft failure	16 (52)
Early eyelid release	16 (52)
Concomitant facial fractures	6 (19)
Mucormycosis (all fatal)	4 (13)

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TIMING OF OPERATIVE INTERVENTION

Among those with combat-related facial burns, the timing of intervention for the facial burn was analyzed against those of other body regions. Compared with subjects who underwent operations on the anterior torso (10.0 ± 1.8 days; P = .00085) or the right hand (10.1 ± 1.0 days; P = .00003), a significant increase was present in the interval from the date of injury to the date of the first region-specific operative intervention to the face. Patients with facial burns received their first facial operation 19.8 ± 2.0 days from the day of injury. Subjects with severe facial burns (7%) received their first region-specific operation sooner at 13.5 ± 2.6 days after the injury (Table 2). The operation for definitive coverage, however, did not occur until 31.9 ± 4.1 days after the injury in those with severe facial burns (7%; Fig 2).

Discussion

Since the start of the present conflict more than 1 decade ago, several studies have attempted to characterize the pattern and management of combat-related burns.[4,5,9,11-14] However, a focus on facial burns has been lacking, despite significant increases in the proportion of combat-related facial burns and the known rehabilitative and reconstructive demands of these injuries.[2,4,7] The purpose of the present study was to review the pattern of facial burn injury encountered at our burn center from October 2001 to February 2011, which captures nearly all the burn injuries from this conflict.

Our analysis has confirmed the findings from previous studies that facial involvement is seen in a significant proportion of combat burn injuries. We found a 6-day interval from the date of injury to the date of the first operative intervention, representative of the obligatory transportation time from the war to our burn center. An expected delay to facial intervention exists compared with interventions performed on other body regions, such as the trunk and hand, resulting in delayed definitive coverage. Severe facial burn injuries were associated with significant mortality and a high rate of inhalational injury, proximal extremity amputations, facial allograft usage, and thin autograft application.

Significantly injured service members must be evacuated out of the theater through several echelons of care before their arrival at our burn center. Although this process has been streamlined in recent years and lessons have been learned to decrease the transport time for significantly injured patients, it still

Table 2. MEAN INTERVAL FROM INJURY TO SURGICAL INTERVENTION

Variable	Face	Severe Facial Burn (FBSA >7%)	Anterior Torso	Right Hand
Total subjects (n)	95	31	35	126
Average DOI to First Op (days)	6.6 ± 0.8	4.5 ± 0.5	5.1 ± 0.5	6.3 ± 0.5
Interval from DOI to First Region Op (days)	13.2 ± 1.9	9.0 ± 2.6	3.9 ± 1.5	3.79 ± 0.8
Interval from First Op to First Region Op (days)	13.2 ± 1.9	9.0 ± 2.6	3.9 ± 1.5	3.79 ± 0.8

Data presented as mean ± standard deviation, unless noted otherwise.

Abbreviations: DOI, date of injury; FBSA, facial burn surface area; First Op, date of first operative intervention; First Region Op, date of first operative intervention in a specific body region.

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requires an average of 5 days. This is reflected in our findings of the interval from the date of injury to the first operation (regardless of anatomic site), consistent with previously reported values.[5] In contrast, the average civilian patient with a burn injury will be transported to a burn center within 24 hours of injury.[5] However, this is still much faster and efficient compared with the previously reported values of a 22-day transport period during the Vietnam War.[15] Faster transit is likely to further improve outcomes, because it adheres to the principles of early excision and grafting, often with the burn eschar removed within 24 hours. However, this is unlikely to change significantly, given the geography of the conflict. It has been suggested that the optimal treatment of full-thickness facial burns is excision and grafting by 10 days after injury, or sooner if the depth of the burn is clearly full thickness, with the goal of having all facial burns that require grafting excised and autogenously grafted by 21 days.[16] Delayed eschar excision has many adverse consequences, including a prolonged inflammatory response and possible infection. Delayed excision and grafting likely contributes to late scarring.[17,18] Thus, an effort should be focused on diminishing the inflammatory response through additional methods, combined with early excision and grafting, without adversely affecting the other body systems. Several investigators have suggested that bathing the eschar in a moist environment along with anti-inflammatory agents either in the form of a wound chamber or a moist gel might be successful and is still under investigation.[19,20]

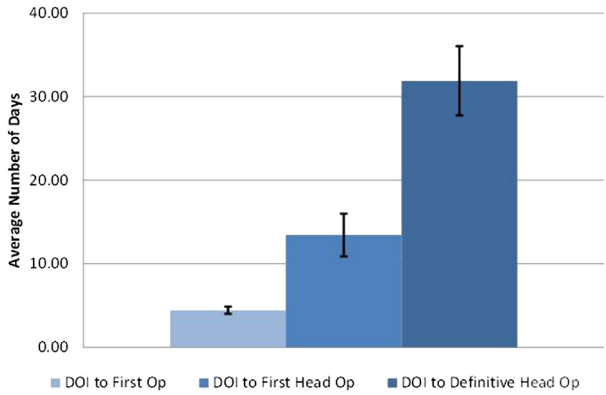

FIGURE 2. The mean date of injury (DOI) to specific operations in military patients with severe facial burns (>7%). This graph shows the interval from the date of injury to the first operation (First Op), first head and neck operation (First Head Op), and the definitive head and neck operation (Definitive Head Op) in the subset of those with severe facial burns (FBSA >7%).

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In the civilian population, in which the transport delay to medical care is generally less of a factor, a patient can usually be transported to a burn center within 24 hours of their initial injury.[5] Although few studies from civilian burn centers have reported the average time from injury to the operative interventions and definitive coverage of the facial burn injuries, it can be assumed that the faster transport to the civilian burn centers would lead to earlier operative intervention of burn injuries such as removal of the eschar and coverage with either allograft or autograft. In a prospective observational study examining the late outcomes of grafting of burned faces, the surgeon debrided the wound at the "earliest opportunity," which was 7 to 10 days, depending on the extent of the other burns. In the present study, the facial wounds were closed no later than 21 days after the burn was incurred.[21]

In the past, the general conception was that facial burns should be treated late to allow the burn to "declare itself." The delayed excisional approach has frequently been favored, because it allows the burn surgeon to better determine the depth of the facial burn. Janzěkovič[22] popularized early tangential excision and grafting of burns, which has become the standard method for both facial and nonfacial burns. However, the acutely burned face, in particular, those with deep and intermediate burns, poses challenges for the surgeon. Using an early excisional strategy decreases the development of edema, inflammation, and scarring.

However, a delayed excisional approach allows additional time for accurate wound depth determination and preservation strategies.[17,23] Additionally, some portions of partial-thickness facial burns will heal spontaneously by 3 weeks with acceptable results. However, areas that have not healed spontaneously will frequently require delayed grafting on a granulation tissue bed, a combination sure to yield disappointing functional and cosmetic results and requiring multiple other grafting and reconstructive procedures.[2,16] In a report by Friedstat and Klein,[24] facial burns were debrided with daily wound care and then assessed at day 10 to determine whether healing would be completed by day 21. They further reported that patients presenting with full-thickness burns with no healing potential should have their wounds excised and grafted within the first 7 to 10 days if the patient's condition is stable and no other areas require urgent excision.[24] According to our data, patients with combat-related facial burns will experience a delay to their first operative encounter and to definitive coverage.

Multiple studies have suggested that deep dermal facial burns must be recognized early to allow for excision and skin grafting to be performed immediately, resulting in faster healing and less scaring.[7,25] The best results will be achieved from color-matched, thick, split-thickness skin grafts from the scalp or "facial blush area" that are 0.018 to 0.025 in. in thickness to minimize contracture. At our center, we have not used this thickness at a mean of 0.0105 in. In the present study population, this was generally not achievable, with definitive closure 31.9 ± 4.1 days after injury. A variety of reasons exist for the delay. These included the 5-day transport time, the presence of deep tissue injury and infection frequently necessitating multiple rounds of debridement, and associated extremity amputations that further limited the donor options.

In our study of severe facial burns, we expected that most of the patients would have some component of a full-thickness injury. The rate of allograft use in our population was fairly high, and even then, the rate of graft failure was high. As such, this was likely related to either inadequate wound bed preparation or postgrafting complications, such as shearing or hematoma. In our experience, inadequate wound bed preparation often occurs in patients with severe facial burns who are immobile and require mechanically controlled ventilation. The face is a unique body region in which partial graft failure is unacceptable and leads to scarring and disrupts the aesthetic unit. In the quest for complete graft success, better technologies are needed to prepare the wound bed and to detect when the wound bed is fully prepared or needs additional preparation. However, few markers are available at present that can reliably and topographically identify a region of a wound that requires additional debridement. Currently, this is done clinically, and most surgeons, over time, develop acumen for deciding the adequacy of a wound debridement. Alternatively, skin substitute grafts, such as allograft, can be applied to "test" a wound bed; however, this will invariably delay the closure of a wound. Thus, an adjunct is clearly needed that will clinically predict a positive response to an allograft, although this could potentially further prolong the inflammatory response. An immediate test of the wound bed is needed to determine whether complete graft success will occur.

Another clinical challenge is obtaining donor sites of appropriate thickness for facial burn grafting. In the comprehensive treatment of these patients, facial reconstruction is significantly compromised by the scarcity of normal skin from donor sites. The correlation is clear, in contrast to combat-related facial burns—the greater the TBSA burn, the greater the percentage of facial burn present. Currently, allogeneic substitutes for facial grafting have yielded diminished cosmetic results compared with autogenous grafts for full-thickness burn injuries to the face. Of the 31 patients with severe facial burns, 9 had undergone at least 1 limb amputation, leaving reduced options for donor sites in this group of subjects, and facial burns are often not the first priority in acute management. Owing to the known metabolic and infectious processes involved in patients with burn injuries, the face is often addressed in a delayed fashion, and our data have supported this finding.

In conclusion, combat-related facial burns are common and difficult injuries to manage. Achievement of improved outcomes among those with combat-related facial burns has been limited by the longer transport times to burn centers, delayed initial and definitive surgical interventions, poor methods for wound bed preparation, the lack of available high-quality, color-matched donor skin, and concomitant injuries. The results of the present study highlight the desperate need for effective anti-inflammatory strategies and high-quality tissue-engineered skin replacements. Our results also emphasize the need for continued documentation on the specific details of facial skin grafting, timing, graft types, and complications. This would allow us to gain additional insight from the present shortcomings.

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Press Release

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