Journal of Surgical Orthopaedic Advances

PRIMARY ARTICLES

Epidemiology of Combat Wounds in Operation Iraqi Freedom and Operation Enduring Freedom: Orthopaedic Burden of Disease

LTC Philip J. Belmont, Jr., MD, MAJ Andrew J. Schoenfeld, MD, and CPT Gens Goodman, DO

The United States forces in Operation Iraqi Freedom/Operation Enduring Freedom (OIF/OEF) are primarily engaged in counterinsurgency operations within an irregular war. The US combat medical experience has reported new injury patterns secondary to the enemy's reliance on explosive mechanisms, particularly improvised explosive devices (IEDs), and the widespread use of individual and vehicular body armor. Musculoskeletal extremity injuries have been reported to comprise approximately 50% of all combat wounds for OIF/OEF. Utilization of individual body armor has dramatically reduced thoracic injuries and has decreased the lethality of gunshot wounds, as measured by the percent killed in action, which in conflicts prior to OIF/OEF was estimated at 33% but is now 4.6%. Explosive mechanisms of injury, with IEDs being the most common, account for over 75% of all combat casualties. The lethality of IEDs coupled with the protection of the thorax and abdomen provided by individual body armor has resulted in increasingly severe orthopaedic injuries. Collection and careful examination of orthopaedic combat casualties will allow for improved military personnel protective measures and treatment of injured soldiers. (Journal of Surgical Orthopaedic Advances 19(1):2–7, 2010)

Key words: casualty, combat, epidemiology, injury, military, wound

The United States has been engaged in 11 major armed conflicts since the American Revolution. Historical aspects of the military medical experience have been documented with varying degrees of completeness from the Civil War to the present. The majority of US armed conflicts prior to the 21st century, with the exception of portions of the Vietnam War, were conducted along the lines of traditional general warfare in which large conventional forces fought for military supremacy by conducting major combat operations. The United States in Operation Iraqi Freedom/Operation Enduring Freedom (OIF/OEF) has predominantly been conducting counterinsurgency operations in an irregular war where there is a violent struggle among state and nonstate actors for legitimacy and influence over the relevant population. Enemy combatants in OIF/OEF use unconventional tactics to counter the traditional advantages of stronger opponents. These asymmetric tactics include such means as terrorism, insurgency, and guerrilla warfare, all of which have been frequently encountered by US and coalition forces in OIF/OEF. The combat medical experience of US military personnel in the irregular warfare of OIF/OEF

From William Beaumont Army Medical Center, El Paso, TX. Address correspondence to: LTC Philip Belmont, MD, Associate Professor, USUHS, Orthopaedic Surgery Service, William Beaumont Army Medical Center/Texas Tech University Health Sciences Center, 5005 N. Piedras, El Paso, TX 79920; e-mail: philip.belmont@us.army.mil.

No external funding or support was received for this study. The findings presented in this article have not been previously presented.

All authors are employees of the US federal government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Department of Defense or the United States Government.

Received for publication September 10, 2009; accepted for publication September 26, 2009.

For information on prices and availability of reprints call 410-494-4994 X226.

1548-825X/10/1901-0002$22.00

presents unique challenges and paradigms that have not been encountered to such an extent in the history of American military medicine.

Combat Casualty Care Statistics

The United States is currently involved in the largest scale armed conflict since the Vietnam War. Historically, disease and non-battle injury (DNBI) have resulted in significantly more hospitalizations and time lost than battle injuries from the hostile combat environment (1–6). However, with the improved treatment and control of infectious disease from World War I to the present conflict (2, 5, 7), there has been a steady decrease in the ratio of DNBI to combat casualties, which during World War I had been 16:1. During the initial phase of OIF, the ratio of DNBI to combat casualties that required hospitalization was 1.75:1 (8). Similarly, a prospective longitudinal cohort study of a US Army Brigade Combat Team during the counterinsurgency operation "The Surge" in OIF from 2006 to 2007 found that among those service members medically evacuated from the theater of operations to a level IV (Germany) or level V (United States) echelon of care, the ratio of DNBI to combat casualties was 1.75:1 (9). Thus, the US military over the course of warfare through the 20th century and into the beginning of the 21st century has seen a ninefold decrease in the ratio of DNBI to combat casualties. The relative increase in the percentage of combat casualties, measured by both hospitalizations and military service members medically evacuated to a level IV echelon of care or higher, has raised the importance of providing optimal treatment to those combat casualties in order to conserve the fighting strength.

Between October 7, 2001 and August 24, 2009, American combat forces in OIF/OEF have sustained over 40,000 casualties with 5117 soldiers dying in theater (10). In OIF alone, 3457 soldiers have been killed in hostile engagements, while a further 31,483 have been wounded in action (WIA) (10). Of those WIA, 9612 (30.5%) required medical evacuation from theater (10). Owens et al. (11) reviewed the spectrum of orthopaedic injuries during OIF/OEF from October 2001 through January 2005. At that time, an estimated 54% of all soldiers injured in these conflicts sustained a musculoskeletal injury to the extremity (11). Similarly, Belmont et al. (9) reported that in an Army Brigade Combat Team during "The Surge" counterinsurgency operation, 49.4% of all soldiers WIA sustained a musculoskeletal injury to the extremity. Based on those findings, if musculoskeletal extremity injuries were extrapolated to comprise 50% of all combat casualties for OIF/OEF to date, there would be approximately 15,741 orthopaedic extremity combat casualties, of which 4806 required medical evacuation from theater. These orthopaedic combat casualty statistics are an underestimate of the total number of orthopaedic combat injuries because they do not include any spine or pelvic combat casualties.

Owens et al. (11) also reported that explosions were responsible for 75% of orthopaedic injuries, while gunshot wounds accounted for 16%. Fifty-three percent of wounds were penetrating injuries to the soft tissues and a further 26% were fractures (11). Eighty-two percent of all fractures were found to have been open injuries (11). Fractures and soft tissue injuries were evenly distributed between the upper and lower extremities, with hand fractures being the most common fracture type in the upper limbs and tibia–fibula fractures most common in the lower limbs (11).

Mechanisms of Injury

There are numerous factors that differentiate the combat medical experience in the present conflict from that encountered in previous wars. Foremost is that US forces in OIF/OEF are primarily engaged in counterinsurgency operations within an irregular war, in which enemy tactics are primarily based on terrorism, insurgency, and guerrilla warfare. There is no uniformed enemy, no defined front lines or order of battle, and allegiances can be fluid (12). As a result, most combat casualties occur due to ambush, or increasingly from the use of improvised explosive devices (IEDs) (9, 13). IEDs are destructive devices constructed from homemade, commercial, or military explosive material that are deployed in ways other than conventional military means. IEDs are designed to destroy, disfigure, or otherwise interdict military assets in the field and include buried artillery rounds, antipersonnel mines, and "car bombs" (14, 15). IEDs have continued to evolve (16) and become a greater threat to US forces and are now estimated to be responsible for 63% of the deaths resulting from combat operations in OIF (13, 17). From June 2003 to June 2009, 1842 coalition soldiers were killed by IEDs in Iraq, and 487 died as a result of similar devices in Afghanistan (18). Recent investigations utilizing the US Joint Theater Trauma Registry have demonstrated that IEDs were responsible for 38% of combat casualties during OIF/OEF from October 2001 through January 2005 (19), and that this increased to 78% of all combat casualties experienced by an Army Brigade Combat Team during "The Surge" operation in OIF from 2006 to 2007 (9). The lethality of IEDs is demonstrated by the recently reported percent killed in action (KIA) rate of 26.5% (9). The percent KIA is defined by the equation, $\%\ \mathrm{KIA} = \mathrm{KIA}/[\mathrm{KIA} + (\mathrm{WIA}-\text{returned to duty})] \times 100$, and represents the percentage of soldiers KIA of those soldiers killed or severely wounded in battle (20). The % KIA provides a measure of lethality of weapons, body

region injured, immediate medic care, and efficiency of evacuation.

Commensurate with the increased use of IEDs, the current conflict has witnessed a substantial increase in the proportion of injuries caused by explosive mechanisms (Fig. 1) (5, 19, 21–23). In addition to IEDs, explosive mechanisms of injury include mortars, rocket-propelled grenades, and landmines. Over the course of the 20th century, a generalized trend has occurred whereby the number of casualties due to explosives has increased relative to those caused by gunshot. In World War I, 65% of all recorded combat casualties resulted from gunshots (21). This decreased to 35% during Vietnam (22) and has been reported to be between 16% and 23% in recent studies of OIF/OEF (9, 11). An analysis of the epidemiology of injuries in OIF/OEF documented that 81% of all injuries were due to explosions (19). The 16%–23% casualty figure for ballistic trauma during OIF/OEF represents the lowest proportion of military wounds from gunshots in history (9, 11, 19).

Distribution of Wounds and the Effects of Individual Body and Vehicular Armor

Wounding patterns during OIF/OEF are also different from those encountered in previous wars (Fig. 2) (5, 19, 22, 23). The distribution of wounds in soldiers WIA is reflected by the different mechanisms of injury. Gunshot wounds most commonly involve single body regions (e.g., head/neck, thorax, abdomen, or extremities) and characteristically have a single entrance and exit wound. In contrast, explosive injuries tend to simultaneously affect multiple body regions. The percentage of head and neck wounds in OIF/OEF has increased relative to prior conflicts, while thoracic and abdominal injuries have decreased (9, 19). The 30%–36% estimate for head and neck wounds encountered for OIF/OEF (9, 19) is double the figure presented for the Vietnam War (22). At the same time, the 5%–7.5% rate of thoracic wounds is the lowest experienced by American military personnel in modern warfare (5, 19, 22, 23). Two recent investigations have found that there was a statistically significant reduction in the percentage of combat extremity wounds for those soldiers who were seriously injured (WIA–returned to duty) during OIF/OEF relative to data from World War II, Korea, and Vietnam (9, 11). However, it should be noted that among those soldiers WIA and not returned to duty, this reduction in extremity wounds is as a percentage of combat wounds and not as a percentage of soldiers sustaining combat wounds.

The changes in wounding patterns can mostly be attributed to the enemy's unconventional tactics in this irregular war (e.g., widespread use of IEDs), as well as the widespread use of individual body armor, Kevlar helmets, and heavily armored vehicles. Individual body armor and Kevlar helmets provide vital protection for the head, chest, and abdomen, mitigating the effect of what would otherwise be life-threatening injuries (15). The reduction in thoracic injuries was first observed in Operation Desert Storm, when individual body armor was employed on a large scale for the first time. This operation saw a decline in thoracic injuries to 5% compared to 13% seen during the Vietnam War (24). A continued reduction in thoracic injuries has also been demonstrated in several studies conducted during OIF/OEF (9, 11, 19, 25).

Since 2006, US Armed Forces have also increasingly deployed mine-resistant ambush-protected vehicles to combat the deleterious effects of IEDs. These vehicles are heavily armored vehicles with "V"-shaped hulls that deflect explosive forces originating below the vehicle away from the passenger compartment. Reports in 2008 attributed a 99% reduction in fatalities from roadside

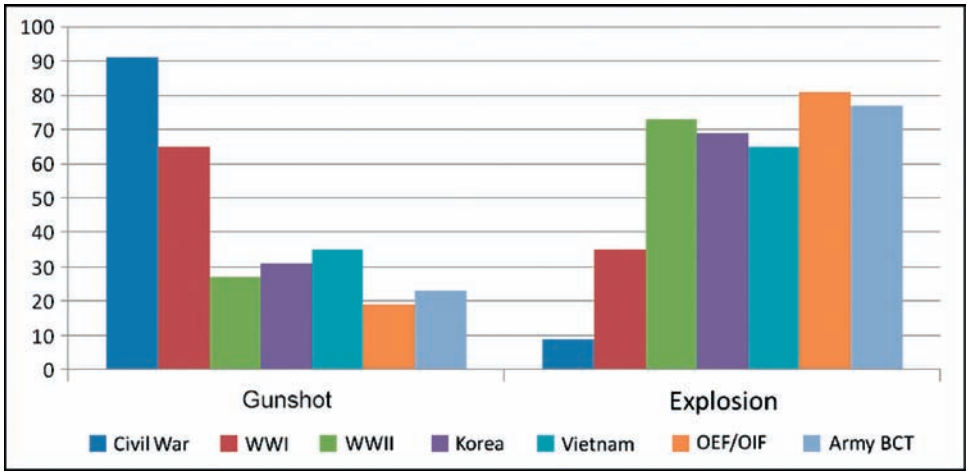

FIGURE 1 Percentage of mechanisms of injury from previous US wars (WIA — RTD).

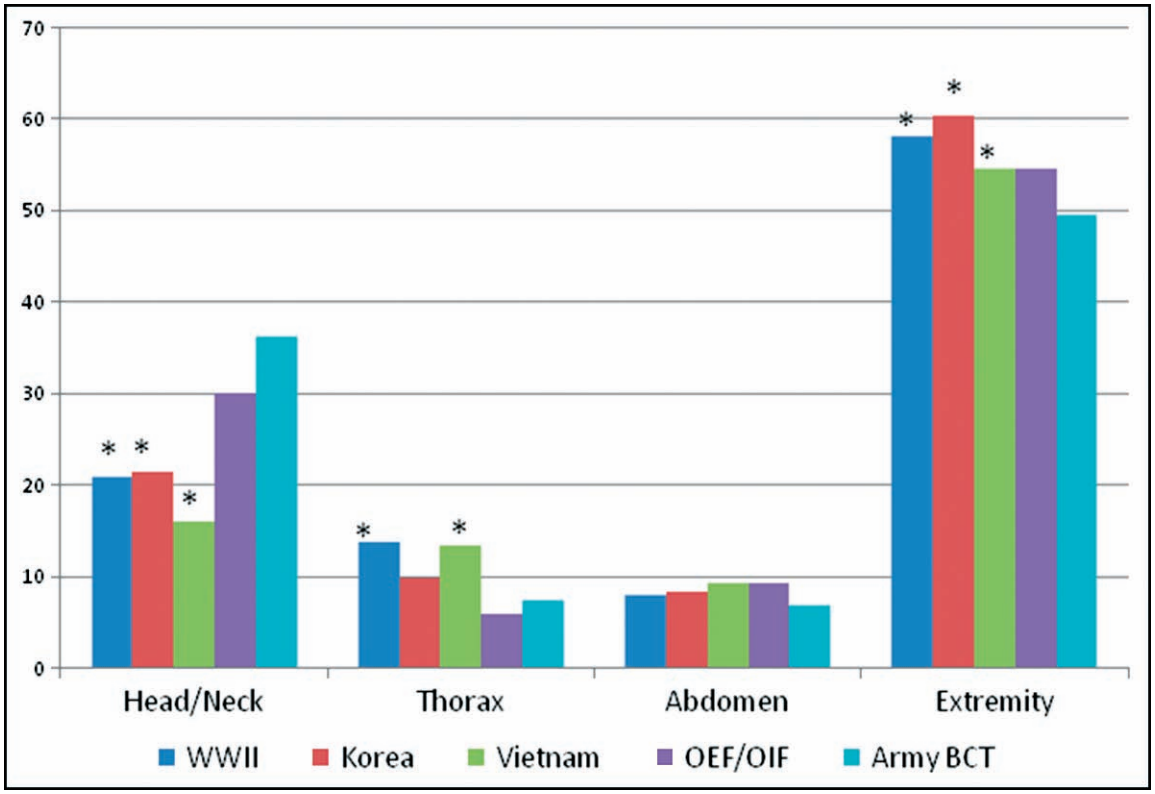

FIGURE 2 Proportional distribution of wounds by body region for combat casualties [WIA — returned to duty (RTD)] from US wars. Asterisks (*) within the same group of graphs represents significant differences of regional wound proportions between wars compared to the referent category Brigade Combat Team (BCT), $p < .05$.

bombs to the use of mine-resistant ambush-protected vehicles (26). As of 2008, only eight soldiers had been killed due to blasts in which mine-resistant ambush-protected vehicles were targeted, and most of those soldiers killed were partially exposed in the vehicle's turret (27).

As a result of such military personnel protective measures, a larger proportion of injuries are being encountered in the unprotected body zones, specifically the extremities and the head and neck region. The blunt impact of blast mechanisms may also be responsible for an increased risk of extremity fracture and injuries to the head and axial skeleton. Similar to the application of airbags and crump zones in civilian vehicular trauma, the use of protective equipment and vehicles increases survivability but also necessitates the treatment of complex wounds that would have previously been fatal. Furthermore, improved battlefield first-aid training, strategic placement of forward surgical teams, decreased time to medical evacuation, and sophisticated surgical care all contribute to an exceptionally low case fatality rate for soldiers injured on the battlefield (9, 12, 20). The case fatality rate provides a measure of overall lethality in those who receive combat wounds and is expressed by the following equation: case fatality rate = (killed in action + died of wounds)/(killed in action + wounded in action) × 100. Case fatality rates for US military ground troops during World War II approached 19.1% (6, 20). The case fatality rate for US military ground troops during Vietnam was reduced to approximately 15.8% (20) and is now estimated to be between 8% and 10% for OIF/OEF (9, 12, 20).

The low case fatality rate does not, however, reflect the severity of injury sustained and, in many cases, soldiers are surviving more significant injuries than ever before. Stansbury et al. (28) conducted a review of the US Joint Theater Trauma Registry and Military Amputee Research Program databases and reported on the rate of major extremity amputations, defined as an amputation proximal to the wrist or ankle. It was found that 7.4% of all casualties with extremity injuries who were unable to return to duty within 72 hours of injury sustained major extremity amputations. Nearly 88% of these amputations were a result of an explosive mechanism, and 18% of these amputees sustained more than one major extremity amputation. Ramasamy et al. (29) provided a descriptive analysis of all combat casualties presenting to a British Military Field Hospital during a 10-month period in 2006 as a result of IED blast. Extremity injuries were found in 86.7% of all casualties. Fractures were present in 52% of all casualties and amputations were reported in 7% of the surviving soldiers and 50% in soldiers KIA or

died of wounds (DOW). These injury patterns not only have important implications for the present conflict, but will also substantially impact the future as the burden of ongoing care for injured soldiers must be borne by the federal government, military treatment facilities, and the Veterans' Administration (30).

Interestingly, despite the improvements in individual and vehicular body armor, the percentage of individuals KIA during OIF/OEF has not been appreciably impacted relative to data from previous conflicts. Over the course of the 20th century, the percentage of casualties KIA remained constant at approximately 20% (20, 31). In OIF, Belmont et al. (9) reported a 22.1% KIA overall, and 26% KIA following explosive injury, demonstrating the effectiveness of the enemy weaponry and tactics. The 3.2% DOW rate encountered in this same investigation compares favorably to the % DOW reported for US ground troops in World War II, Korea, Vietnam, and the initial stages of OIF/OEF, which ranged from 3.2% to 6.7% (20, 31). On a more positive note, the lethality of gunshot wounds in conflicts prior to OIF/OEF was estimated at 33% (31), but data from OIF reveals a reduction in lethality following such injuries to 4.6% (9).

In conclusion, despite the experience gained during these conflicts and the technical improvements made by our military surgeons, the evolution of enemy tactics has continued to result in a large burden of complex orthopaedic injuries. The evolution of tactics utilizing highly lethal IEDs in addition to guns, bombs, and antipersonnel mines have afforded the enemy a greater capability to take life and injure soldiers. Collection and careful examination of combat casualty care statistics, with an emphasis on the orthopaedic combat casualties for continued operations in Iraq and Afghanistan, will allow the military medical system to more effectively treat deployed soldiers. Additionally, the information uncovered by careful examination of these statistics may also provide the impetus for the leadership of the US Armed Forces to continue to improve upon personnel protective measures, such as individual body armor and the mine-resistant ambush-protected vehicle, in order to protect US military service members and conserve the fighting strength.

Acknowledgments

The authors thank Madra Belmont for her editorial contributions to the work.

References

1. Champion, H. R., Bellamy, R. F., Roberts, P., et al. A profile of combat injury. J. Trauma 54:S13–19, 2003.
2. Hoeffler, D. F., Melton, L. J. Changes in the distribution of Navy and Marine Corps casualties from World War I through the Vietnam Conflict. Mil. Med. 146:776–779, 1981.
3. Holland, B. D., Long, A. P. Cost of non-battle injuries and diseases compared to battle casualties. Mil. Med. 117(1):46–50, 1955.
4. Palinkas, L. A., Coben, P. Disease and non-battle injuries among U.S. Marines in Vietnam. Mil. Med. 153(3):150–155, 1988.
5. Reister, F. A. *Battle Casualties and Medical Statistics: US Army Experience in the Korean War*. The Surgeon General, Department of the Army, Washington, DC, 1973.
6. Reister, F. A. *Medical Statistics in World War II*. The Surgeon General, Department of the Army, Washington, DC, 1975.
7. Writer, J. V., DeFraites, R. F., Keep, L. W. Non-battle injury casualties during the Persian Gulf War and other deployments. Am. J. Prev. Med. 18(3S):64–70, 2000.
8. Zouris, J. M., Wade, A. L., Magno, C. P. Injury and illness casualty distributions among U.S. Army and Marine Corps personnel during Operation Iraqi Freedom. Mil. Med. 173:247–252, 2008.
9. Belmont, P. J., Goodman, G. P., Zacchilli, M., et al. Incidence and epidemiology of combat injuries sustained during "The Surge" portion of Operation Iraqi Freedom by a US Army Brigade Combat Team. J. Trauma 2010 (In press).
10. Directorate for Information Operations and Reports. Department of Defense. Available at: http://siadapp.dmdc.osd.mil/personnel/CASUALTY/castop.htm. Accessed August 24, 2009.
11. Owens, B. D., Kragh, J. F., Jr., Macaitis, J., et al. Characterization of extremity wounds in Operation Iraqi Freedom and Operation Enduring Freedom. J. Orthop. Trauma 21:254–257, 2007.
12. Covey, D. C. From the frontlines to the home front: the crucial role of military orthopaedic surgeons. J. Bone Joint Surg. 91-A:998–1006, 2009.
13. Bird, S. M., Fairweather, C. B. Military fatality rates (by cause) in Afghanistan and Iraq: a measure of hostilities. Int. J. Epidemiol. 36:841–846, 2007.
14. Covey, D. C. Blast and fragment injuries of the musculoskeletal system. J. Bone Joint Surg. 84-A:1221–1234, 2002.
15. Mazurek, M. T., Ficke, J. R. The scope of wounds encountered in casualties from the global war on terrorism: from the battlefield to the tertiary treatment facility. J. Am. Acad. Orthop. Surg. 14:S18–S23, 2006.
16. Atkinson, R. The IED problem is getting out of control. We've got to stop the bleeding. *Washington Post*, September 30, 2007. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2007/09/29/AR2007092900751.html?sid=ST2007092900754. Accessed August 25, 2009.
17. Eisler, P. The truck the pentagon wants and the firm that makes it. *USA Today*, August 1, 2007. Available at: http://www.usatoday.com/news/military/2007-08-01-force-protection-mraps_N.htm. Accessed August 25, 2009.
18. icasualties.org. Iraq coalition casualty count. Available at: http://icasualties.org/Iraq/IED.aspx. Accessed August 25, 2009.
19. Owens, B. D., Kragh, J. F., Wenke, J. C., et al. Combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom. J. Trauma 64:295–299, 2008.
20. Holcomb, J. B., Stansbury, L. G., Champion, H. R., et al. Understanding combat casualty care statistics. J. Trauma 60:397–401, 2006.
21. Beebe, G. W., DeBakey, M. E. Death from wounding. In *Battle Casualties*, pp. 74–147, Charles C Thomas, Springfield, IL, 1952.
22. Hardaway, R. M. Viet Nam wound analysis. J. Trauma 18:635–643, 1978.
23. Beebe, G. W., DeBakey, M. E. Location of hits and wounds. In *Battle Casualties*, pp. 165–205, Charles C Thomas, Springfield, IL, 1952.

24. Uhorchak, J. M., Rodkey, W. G., Hunt, M. M., et al. *Institute Report 469: Casualty Data Assessment Team Operation Desert Storm*. Letterman Army Institute of Research, San Francisco, CA, 1992.
25. Holcomb, J. B., McMullin, N. R., Pearse, L., et al. Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. Ann. Surg. 245:986–991, 2007.
26. Vanden Brook, T. Pentagon: New MRAPs saving troops' lives. *USA Today*, April 4, 2008. Available at: http://www.usatoday.com/news/military/2008-04-03-MRAPs_N.htm. Accessed August 25, 2009.
27. Knight Ridder. New concerns after 2 die in MRAP. Military.com. May 6, 2008. Available at: http://www.military.com/news/article/new-concerns-after-2-die-in-mrap.html. Accessed August 25, 2009.
28. Stansbury, L. G., Lallis, S. J., Branstetter, J. G., et al. Amputations in U.S. military personnel in the current conflicts in Afghanistan and Iraq. J. Orthop. Trauma 22(10):43–46, 2008.
29. Ramasamy, A., Harrisson, S. E., Clasper, J. C., et al. Injuries from roadside improvised explosive devices. J. Trauma 65:910–914, 2008.
30. Masini, B. D., Waterman, S. M., Wenke, J. C., et al. Resource utilization and disability outcome assessment of combat casualties from Operation Iraqi Freedom and Operation Enduring Freedom. J. Orthop. Trauma 23:261–266, 2009.
31. Bellamy, R. F. Combat trauma overview. In Zajtchuk R, Grande CM eds. *Textbook of Military Medicine, Anesthesia and Perioperative Care of the Combat Casualty*, pp. 1–42, edited by R. Zajtchuk, C. M. Grande, Office of the Surgeon General, Department of the Army, United States Army, Falls Church, VA, 1995.

During Operations Iraqi Freedom and Enduring Freedom, extremity injury accounted for 54% of all wounds, and these injuries required 64% of resource utilization. 8,9 Extremity soft tissue injuries were both common and had a significant impact on the fighting force resulting in significant disability.Â Orthopaedic injuries sustained in Operation Enduring Freedom from December 2001 to January 2003 that were treated in forward-deployed military medical facilities and evacuated to a U.S. army medical center were reviewed. The spectrum of injuries included open fractures, amputations, neurovascular, and soft-tissue injuries.Â The primary mission of a US military ICU deployed in support of combat operations is the care of its injured troops. 1 Journal of Surgical Orthopaedic Advances PRIMARY ARTICLES Epidemiology of Combat Wounds in Operation Iraqi Freedom and Operation Enduring Freedom: Orthopaedic Burden of Disease LTC Philip J. Belmont, Jr., MD, MAJ Andrew J. Schoenfeld, MD, and CPT Gens Goodman, DO The United States forces in Operation Iraqi Freedom/Operation Enduring Freedom (OIF/OEF) are primarily engaged in counterinsurgency operations within an irregular war.Â Musculoskeletal extremity injuries have been reported to comprise approximately 50% of all combat wounds for OIF/OEF. Utilization of individual body armor has dramatically reduced thoracic injuries and has decreased the lethality of gunshot wounds, as The biggest contribution of psychological operations in Operation IRAQI FREEDOM was to persuade very large numbers of Iraqâ€™s military forces to abandon their weapons and go home. Psychological messages reduced popular resistance to the invasion by promising freedom and a better future.Â By the start of formal combat operations, the number of dropped leaflets totaled more than 20 million. The themes and messages that the PSYOP leaflets conveyed included capitulation; deterrence of WMDs; the preservation of Iraqi oil fields and the radio frequencies for coalition broadcasts.Â During Operation Iraqi Freedom and Operation Enduring Freedom these bombers were used to both bomb and leaflet Iraq and Afghanistan.