Dismounted Complex Blast Injuries: Patterns of Injuries and Resource Utilization Associated with the Multiple Extremity Amputee

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The objective of this report is to analyze the resource utilization and injury patterns of complex dismounted blast injuries. A retrospective review of U.S. service members injured in combat between 2007 and 2010 was conducted. Data analyzed included age, injury mechanism, amputated limbs, number and type of associated injuries, blood products utilized, intensive care unit length of stay (ILOS), hospital length of stay (HLOS) and the Injury Severity Score (ISS). Patients were stratified based on the number of amputations. Sixty-three patients comprised the multiple extremity amputation (MEA) group. Ninety-eight percent sustained injuries from an improvised explosive device (IED) and 96% were dismounted. The ISS, number of surgical encounters, blood products utilized and ILOS were all clinically significantly different than controls. Care of multiple extremity amputees involves the utilization of significant resources. This knowledge may better help surgeons and administrators allocate assets at hospitals, both military and civilian, who care for this complex and challenging patient population. (Journal of Surgical Orthopaedic Advances 21(1):32–37, 2012)

Key words: dismounted, blast, amputations, resources, injury severity score, ISS, multiple

Introduction

Historically, the rate of multiple extremity amputations in armed conflicts has been relatively low. In the early conflicts of the 20th century, from World War I to the Korean War, the multiple extremity amputation rate ranged from 2% to 8% of all patients sustaining at least one amputation (1,2). This rate may have been suppressed due to relatively lower energy weapons or due to a lower survivability rate (3). Data from the Vietnam conflict suggest that 18% of amputees sustained more than one major extremity amputation (4). Data covering the first 6 years of the Global War on Terror, including Operation Iraqi Freedom and Operation Enduring Freedom, mirrored data from the Vietnam conflict with a multiple extremity amputation rate averaging 18% (1). Based on our clinical experience, we hypothesize the rate to be significantly higher.

Multiple extremity amputations represent a devastating, complex injury pattern and the increased prevalence of these injuries may be due to more substantial injuries being sustained, or to increased survivability from severe injuries due to advances in body armor or resuscitative techniques. Injury severity has been reported to have increased during different periods of the current conflicts in Afghanistan and Iraq (5); however, the survivability rate has remained stable with the corresponding increase injury severity (6). This increased survivability during the current

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The authors certify that all individuals who qualify as authors have been listed; each has participated in the conception and design of this work, the analysis of data, the writing of the document, and the approval of the submission of this version; that the document represents valid work; that if we used information derived from another source, we obtained all necessary approvals to use it and made appropriate acknowledgements in the document; and that each takes public responsibility for it. Nothing in the presentation implies any Federal/DOD/DON endorsement.

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conflict has been attributed to multiple factors, including the increased use of tourniquets, improved tactical combat casualty care, enhanced body armor, more effective transfusion protocols, and rapid evacuation to higher levels of surgical care (7,8). Moreover, when compared to previous studies exploring injury survivability, there has been anecdotal evidence that the survivability of the multiple extremity amputee in particular has increased.

The increasing number of patients sustaining this complex injury pattern emphasizes the need for studies documenting resource requirements in an effort to provide optimal care. Civilian patients that have sustained multiple extremity injuries have been found to require almost twice the medical resources for treatment and have significantly more disability compared to a control group (9). Additionally, combat-related extremity injuries have been shown to require significantly more resources and have more disability than controls (10). However, there are no published reports documenting the injury patterns associated with the multiple extremity amputee or the resources utilized during definitive management of their injuries. Therefore, the purpose of this report is to document the associated injuries and the resource utilization associated with the multiple-extremity amputee.

Methods

The Combat Trauma Registry (CTR) is a database of active duty services members injured in combat and treated exclusively at the National Naval Medical Center (NNMC). Information is obtained from records accompanying patients and includes data from the point of injury through the echelons of care. The data is entered and updated in the CTR by a dedicated certified trauma registrar.

The Institutional Review Board (IRB) at the former NNMC approved a review of the CTR. The CTR was queried for all U.S. service members admitted to NNMC secondary to injuries sustained in support of Operation Iraqi Freedom and Operation Enduring Freedom between September 2007 and December 2010. Patients with major extremity amputations, defined as loss of a limb at or proximal to the radiocarpal or tibiotalar joints, were identified. As a measure of hospital resource utilization, blood products utilized, intensive care unit length of stay (ILOS), hospital length of stay (HLOS), and the number of operative periods utilized were extracted. Additional data extracted included the number and type of extremity(s) amputated, number and type of associated injuries, and the injury severity as measured by the Injury Severity Score (ISS). Associated injuries were categorized into general anatomic areas including abdominal, thoracic, neurologic, vascular, urinary, and skeletal.

Statistical Analysis

Queried data on all patients in the study was directly extracted from the CTR and recorded utilizing Excel (Microsoft Corporation, Redmond, WA). Data was analyzed utilizing StatPlus: Mac statistical analysis program for Mac OS, Version 2009 (AnalystSoft Inc., Alexandria, VA). Univariate analyses were performed using 2-sample Student t-tests for continuous numerical variables. Statistical significance was set at $p < 0.05$. Interval data is listed as a mean +/− the standard deviation (SD).

Results

There were 685 U.S. trauma casualties in the CTR. One hundred thirteen (16%) patients sustained at least one traumatic amputation. Four of the patients had incomplete data and were excluded. This left 109 patients with major traumatic amputation for analysis. Sixty-three (57%) sustained more than one major extremity amputation. Five patients (4%) died from their wounds, all of whom sustained multiple extremity amputees. US Marines accounted for the majority of the wounded combatants, as NNMC is a Naval Hospital. The majority of the injuries were blast injuries secondary to an improvised explosive device (IED) (Table 1).

The 63 patients in the multiple extremity amputation (MEA) group sustained a total of 137 amputations. All of the MEA group patients sustained bilateral lower extremity amputations. Figure 2 shows a representation of the injury pattern. The most common amputation pattern was bilateral transfemoral followed by bilateral transtibial amputations (Table 2). The mean age of the MEA group was 23.5 ± 3.86 (range, 19 to 39) years old. The mean

TABLE 1 Summary of demographics

	MEA	SEA	*P*
Number	63	46	
Hospital LOS	33	28	$p = 0.059$
ICU LOS	9.3	3.7	$p = 0.004$
Number Injuries	6.6	6.1	$p = 0.24$
Blood Utilization	19.5	6.1	$p < 0.005$
Surgical Interventions	8.6	3.9	$p < 0.005$
ISS	21	17	$p = 0.019$
Age	23.5	22.9	$p = 0.23$
Sex – Male	63	46	
Mechanism of Injury			
IED	62	37	
Anti-Personnel Mine	1	2	
Suicide Bomber		1	
RPG		1	
VBIED		1	
Helicopter Crash		1	
GSW		2	
Mortar		1	

age of the SEA group was 22.9 ± 3.95 (range, 18 to 38) years old. Sixty-two (98%) of the MEA sustained injuries secondary to an IED. Sixty-one (96%) were dismounted. Thirty-seven (80%) of the single extremity amputation (SEA) injuries were secondary to an IED blast.

The MEA group sustained a mean 6.6 ± 3.87 (range, 0 to 16) associated injuries. The most frequently encountered associated injuries included musculoskeletal injuries (fractures, dislocations or digit amputations) followed by soft tissue wounds and injuries to the genitourinary system (Table 3).

The MEA group utilized a mean 19.5 ± 18.2 (range, 0 to 104) units of packed red blood cells and had a mean HLOS of 33 (range, 7 to 88) days and a mean ILOS of 9.3 ± 13.7 (range, 0 to 69) days. The mean number of operative interventions was 8.6 (range, range 3 to 17). The average ISS for the MEA group was 21 ± 7.74 (range, 9 to 42) (Table 1). All patients that died sustained multiple extremity amputations and had a mean ISS of 24.

The 46 patients that sustained a SEA included 26 transtibial amputations, 10 transfemoral amputations, two knee disarticulations, three ankle disarticulations, three wrist disarticulations, and two transhumeral amputations. This group sustained a mean of 6.1 ± 4.1 (range, 0 to 16) injuries additional injuries. The most frequently encountered associated injuries were integumentary (67), musculoskeletal (66), and genitourinary (29).

Of note, there was no significant difference between the MEA and SEA group in regards to head or CNS injury (Figure 1).

The SEA group utilized a mean of 6.08 ± 6.03 (range, 0 to 23) units of packed red blood cells, had a mean HLOS of 28.73 (range, 9 to 76) days and a mean ILOS of 3.73 (range, 0 to 34) days. The mean number of operative procedures was 3.9 (range, 0 to 13). The average ISS for the SEA group was 17.5 ± 9.69 (range, 9 to 43) (Table 1).

TABLE 2 Distribution of amputation patterns

Location	Number
AKA, AKA	20
BKA, BKA	13
AKA, BKA	8
BKA, KD	5
AKA, KD	5
AKA, AKA, TE	3
AKA, AKA, TH	2
AKA, HD	2
AKA, AKA, TR, TR	1
AKA, AKA, TR	1
AKA, AKA, TR, TH	1
KD, KD	1
HD, HD, TR	1
Total	63

Note: AKA, Above Knee Amputation (transfemoral); KD, Knee Disarticulation; TR, Transradial Amputation; HD, Hip Disarticulation; TE, Through Elbow Amputation; BKA; Below Knee Amputation (transtibial); TH; Transhumeral Amputation.

TABLE 3 MEA associated injuries

Region	Number
MSK	128
Integumentary	77
GU	71
Pelvis/Perineum	23
Ear	19
Abdomen	17
Thoracic	15
Spine	13
Neurologic	12
Vascular	11
Face Fx	10
Eye	8
Oral Wounds	4

Discussion

Operations Iraqi Freedom and Enduring Freedom are the largest and longest-running U.S. conflicts since Vietnam. Since the wars began in October 2001, over 1,100 service members have sustained a major extremity amputation (1). This study is the first to focus on the dismounted complex blast injured multiple extremity amputee, documenting both their associated injuries as well as the acute hospital resource utilization associated with their definitive care.

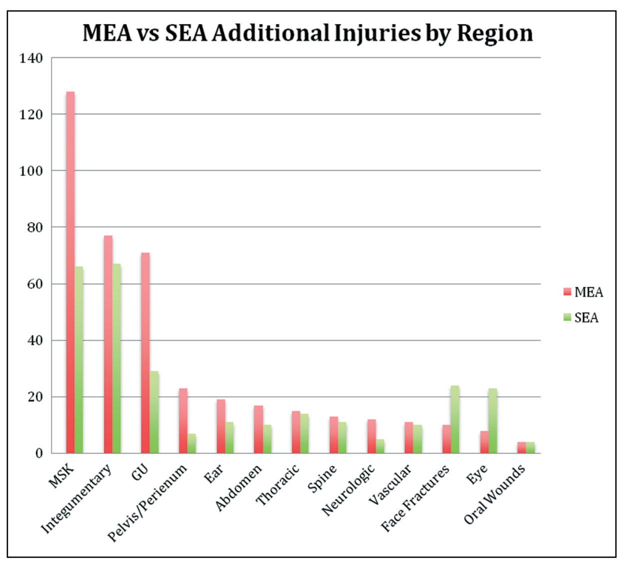

FIGURE 1 Additional Injuries by body region. MSK, Musculoskeletal; GU, Genitourinary.

TABLE 4 Median HLOS and ICU LOS versus ISS

Copes' Severity Score*	ISS	Multiple Extremity Amputation Group No.	Median HLOS	ILOS	Deaths	Single Extremity Amputee Group No.	HLOS	ILOS	Deaths
A	1 to 3	0	*na*	*na*	*na*	0	*na*	*na*	*na*
B	4 to 8	0	*na*	*na*	*na*	0	*na*	*na*	*na*
C	9 to 15	10	27.7	8.6	1	25	24.2	0.56	0
D	16–24	36	30.7	5.3	1	12	28.6	4.6	0
E	25–49	17	42.9	17.3	3	9	41.5	11.3	0
F	50–66	0	*na*	*na*	*na*	0	*na*	*na*	*na*
G	75	0	*na*	*na*	*na*	0	*na*	*na*	*na*
	Total	63	33.7	9.3	5	46	28.7	3.7	0

Note: ISS, Injury Severity Score; HLOS, Hospital Length of Stay; ILOS, Intensive Care Unit Length of Stay; na, not applicable (no patients fell within the Copes' Severity Score category).

*To allow for statistical analysis across a broad range of ISS values, ISS are grouped in categories based on the maximum AIS score. Adapted from Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The Injury Severity Score revisited. J Trauma. 1988 Jan;28(1):69–77.

FIGURE 2 Representation injury pattern, including bilateral lower extremity amputation, with mangled or amputated upper extremity.

Healthcare resource utilization can be defined by several measures (11,12). In this study, the metrics by which resource utilization was evaluated included: hospital length of stay, ICU length of stay, number of surgical encounters, and blood product utilization.

We observed there was no significant difference in the hospital length of stay between the MEA group and the SEA group. This is a similar finding to those reported by Shai, who suggested an association between the Injury severity score and length of stay in war casualties (13). The authors also suggest a possible explanation in the form of a selection bias. In the present study, after controlling for ISS, an increased hospital length of stay was encountered (Table 4).

We observed a longer ICU stay requirement for the MEA group when compared to the SEA group. All multiple extremity amputation patients are transported via a Critical Care Air Transport Team (CCATT) from Landsthul Regional Medical Center to the NNMC, and by policy are admitted directly to the intensive care unit and monitored for at least 24 hours. Those patients that meet ICU discharge criteria are then transferred to the floor. Although there are no published reports exploring ICU requirements and the MEA, Bederman et al. reported an increased ICU requirement for the polytraumatized patient with increased ISS (14).

Accordingly, we observed significantly more blood product utilization in the MEA group. Repeated surgical interventions and debulking large surface areas of muscle often results in significant blood loss and the requirement to administer multiple blood products. Additionally, due to the increased deep venous thrombosis rate in the MEA, chemoprophylaxis with anticoagulants are routinely continued during their frequent operative interventions. Gillern et al. illustrated that bilateral lower extremity trauma-associated amputations was an independent risk factor for the development of a pulmonary embolism (15). The indications for prescribing blood products were not standardized. Dunne et al. illustrated that blood product administration was an independent risk factor for infection and increased resource utilization (16).

The MEA patients underwent significantly more operative interventions than the isolated extremity amputee. While the number trips to the operating room provide an indication of increased resource utilization, the total operative experience is likely under-represented. Due to the nature of these injuries, most cases require multidisciplinary teams of surgeons simultaneously or consecutively during the same operating room trip including trauma surgeons, orthopedic trauma surgeons, urologist, plastic surgeons, and orthopedic hand surgeons. Abdominal, perineal, and extremity injuries were frequently addressed simultaneously.

IEDs were the predominant means of injury in the MEA group in contrast to the single extremity amputation group. The injuries caused by the blast create primary through quaternary mechanisms of injury (17–19). The secondary blast injury is the source of the amputations (20) and is caused by fragments and debris that penetrates through the casualty (18). The secondary blast injury may additionally account for the extensive perineal and genitourinary injuries.

When comparing the number of associated injuries between the MEA and SEA groups, we observed no statistically significant difference. However, the increased ISS scores observed in the MEA group suggest more severe associated injuries in this group. This is in contrast to studies suggesting that the ISS underestimates injury severity in the multiple extremity-injured patient (21–23).

Urologic injuries were one of the most frequently encountered associated injuries (Table 3) in the MEA group and included injuries to the external genitalia as well as the bladder and urethra. Serkin et al. examined urologic injuries in recent casualties from OEF/OIF and found that the distribution and percentage of casualties with GU injuries was similar to those of previous conflicts (24). The authors concluded that personal protective equipment should be given to service members serving in geographic areas associated with increased GU injuries and pre-deployment training being provided to medical providers who care for these injuries. Nevertheless, the frequency of these injuries highlights the need for further research into body armor and personal protective equipment designed to protect these sensitive area from harm.

The limitations of this study stem from its retrospective nature and that it includes patients evacuated to a single tertiary care military facility. Furthermore, these calculations include only resource utilized during a single hospitalization at one institution and does not capture resources consumed during followup treatment in an inpatient or outpatient rehabilitation setting if patients were discharged to a Veteran's Affairs or Department of Defense rehabilitation facility for amputation rehabilitation where additional surgeries may have occurred. This is important because both civilian and military studies have illustrated a significant reoperation rate associated with amputation complications (25,26)

Conclusion

Greater than 18% of U.S. casualties from Operation Iraqi Freedom and Operation Enduring Freedom have sustained more than one MEA secondary to IEDs, with bilateral transfemoral amputations being the most common injury pattern. Fractures or dislocations, soft tissue wounds, and genitourinary trauma are the most frequently encountered associated injuries. These patients utilized more resources, including blood products and increased ICU days, and underwent more operative interventions than SEAs. This study illustrates the increased number of resources that must be allocated to the MEA. Knowledge of this increased resource utilization may help surgeons and medical administrators allocate assets at hospitals, both military and civilian, dedicated to caring for this complex and challenging patient population.

References

1. Stansbury, L. G., Lalliss, S. J., Branstetter, J. G., Bagg, M. R., Holcomb, J. B. Amputations in U. S. military personnel in the current conflicts in Afghanistan and Iraq. J. Orthop. Trauma. 22(1):43–6, 2008. http://dx.doi.org/10.1097/BOT.0b013e31815b35aa
2. Potter, B. K., Scoville, C. R. Amputation is not isolated: an overview of the US Army Amputee Patient Care Program and associated amputee injuries. J. Am. Acad. Orthop. Surg. 14(10 Spec No.):S188–90, 2006. Review.
3. Peterson, L. T. Administrative considerations in the amputation program. In: Cleveland M, Shands AR, McFetridge EM, eds. Surgery in World War II: Orthopedic Surgery in the Zone of the Interior. Washington, DC: Office of the Surgeon General. 871–872, 1970.
4. Mayfield, G. W. Vietnam War Amputees. In: Burkhalter WE: Surgery in Vietnam: Orthopedic Surgery. Washington, DC: Office of the Surgeon General. 131–153, 1994.
5. Kelly, J. F., Ritenour, A. E., McLaughlin, D. F., et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. J. Trauma. 64(2 Suppl):S21–6, 2008. http://dx.doi.org/10.1097/TA.0b013e318160b9fb
6. Ritenour, A. E., Blackbourne, L. H.; Kelly, J. F. Incidence of Primary Blast Injury in US Military Overseas Contingency Operations –A Retrospective Study. Ann. Surg. 251(6):1140–1144, 2010.
7. Beekley, A. C., Sebesta, J. A., Blackbourne, L. H., et al. Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. J Trauma. 64(2 Suppl):S28–37, 2008. http://dx.doi.org/10.1097/TA.0b013e318160937e
8. Kragh, J. F., Jr., Walters, T. J., Baer, D. G., et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. Ann. Surg. 249(1):1–7, 2009. http://dx.doi.org/10.1097/SLA.0b013e31818842ba
9. Fern, K. T., Smith, J. T., Zee, B., et al. Trauma patients with multiple extremity injuries: resource utilization and long-term outcome in relation to injury severity scores. J. Trauma. 45(3):489–94, 1998. http://dx.doi.org/10.1097/00005373-199809000-00010
10. 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(4):261–6, 2009. http://dx.doi.org/10.1097/BOT.0b013e31819dfa04
11. Agency for Healthcare Research and Quality; Date accessed: 03/27/2011; http://www.ahrq.gov/qual/perfmeasguide/perfmeaspt3.htm
12. Healthcare Cost & Utilization Project. Rockville, MD: AHRQ. Available at: http://www.ahrq.gov/data/hcup; Accessed: 03/27/2011
13. Linn, S., Linn, R., Sheps, S., et al. Injury severity scoring and length of stay in hospital of war casualties–demonstration of an association and possible selection bias. Int. J. Epidemiol. 22(5):905–10, 1993. http://dx.doi.org/10.1093/ije/22.5.905
14. Bederman, S. S., Murnaghan, O., Malempati, H., et al. In-Hospital Mortality and Surgical Utilization in Severely Polytraumatized Patients With and Without Spinal Injury. J. Trauma. 2011.
15. Gillern, S. M., Sheppard, F. R., Evans, K. N., et al. Incidence of pulmonary embolus in combat casualties with extremity amputations and fractures. J. Trauma. 71(3):607–12, 2011. http://dx.doi.org/10.1097/TA.0b013e3182282574
16. Dunne, J. R., Riddle, M. S., Danko, J., Hayden, R., Petersen, K. Blood transfusion is associated with infection and increased resource utilization in combat casualties. Am. Surg. 72(7):619–25, 2006.
17. Champion, H. R., Holcomb, J. B., Young, L. A. Injuries from explosions: physics, biophysics, pathology, and required research focus. J. Trauma. 66(5):1468–77; discussion 1477, 2009. Review. http://dx.doi.org/10.1097/TA.0b013e3181a27e7f
18. Ritenour, A. E., Blackbourne, L. H., Kelly, J. F., et al. Incidence of primary blast injury in US military overseas contingency operations: a retrospective study. Ann. Surg. 251(6):1.140–4, 2010. http://dx.doi.org/10.1097/SLA.0b013e3181e01270
19. Champion, H. R., Holcomb, J. B., Young, L. A. Injuries from explosions: physics, biophysics, pathology, and required research focus. J. Trauma. 66(5):1468–77; discussion 1477, 2009. Review. http://dx.doi.org/10.1097/TA.0b013e3181a27e7f
20. Centers for Disease Control. Explosions and blast injuries: a primer for clinicians. Centers for Disease Control; 2007, Atlanta, GA. Ritenour AE, Baskin TW. Primary blast injury: update on diagnosis and treatment. Crit. Care Med. 36(7 Suppl):S311–7, 2008. Review.
21. Michaels, A. J., Madey, S. M., Krieg, J. C., Long, W. B. Traditional injury scoring underestimates the relative consequences of orthopedic injury. J. Trauma. 50(3):389–95, 2001. http://dx.doi.org/10.1097/00005373-200103000-00001
22. Poole, G. V., Tinsley, M., Tsao, A. K., et al. Abbreviated Injury Scale does not reflect the added morbidity of multiple lower extremity fractures. J. Trauma. 40(6):951–4, 1996. http://dx.doi.org/10.1097/00005373-199606000-00014
23. Balogh, Z. J., Varga, E., Tomka, J., et al. The new injury severity score is a better predictor of extended hospitalization and intensive care unit admission than the injury severity score in patients with multiple orthopaedic injuries. J. Orthop. Trauma. 17(7):508–12, 2003. http://dx.doi.org/10.1097/00005131-200308000-00006
24. Serkin, F. B., Soderdahl, D. W., Hernandez, J., et al. Combat urologic trauma in US military overseas contingency operations. J. Trauma. 69 Suppl 1:S175–8, 2010. http://dx.doi.org/10.1097/TA.0b013e3181e45cd1
25. Tintle, S. M., Forsberg, J. A., Keeling, J. J., Shawen, S. B., Potter, B. K. Lower extremity combat-related amputations. J. Surg. Orthop. Adv. 19(1):35–43, 2010.
26. Harris, A. M., Althausen, P. L., Kellam, J., et al. Complications following limb-threatening lower extremity trauma. J. Orthop. Trauma 23(1):1–6, 2009. http://dx.doi.org/10.1097/BOT.0b013e31818e43dd