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Injury Severity and Causes of Death From Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 Versus 2006

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Background: **The opinion that injuries sustained in Iraq and Afghanistan have increased in severity is widely held by clinicians who have deployed multiple times. To continuously improve combat casualty care, the Department of Defense has enacted numerous evidence-based policies and clinical practice guidelines. We hypothesized that the severity of wounds has increased over time. Furthermore, we examined cause of death looking for opportunities of improvement for research and training.**

Methods: **Autopsies of the earliest combat deaths from Iraq and Afghanistan and the latest deaths of 2006 were analyzed to assess changes in injury severity and causes of death. Fatalities were classified as nonsurvivable (NS) or potentially survivable (PS). PS deaths were then reviewed in depth to analyze mechanism and cause.**

Results: **There were 486 cases from March 2003 to April 2004 (group 1) and 496 from June 2006 to December 2006 (group 2) that met inclusion criteria. Of the PS fatalities (group 1: 93 and group 2: 139), the injury severity score was lower in the first group (27 ± 14 vs. 37 ± 16, $p < 0.001$), and had a lower number of abbreviated injury scores ≥4 (1.1 ± 0.79 vs. 1.5 ± 0.83 per person, $p < 0.001$). The main cause of death in the PS fatalities was truncal hemorrhage (51% vs. 49%, p = NS). Deaths per month between groups doubled (35 vs. 71), whereas the case fatality rates between the two time periods were equivalent (11.0 vs. 9.8, p = NS).**

Discussion: **In the time periods of the war studied, deaths per month has doubled, with increases in both injury severity and number of wounds per casualty. Truncal hemorrhage is the leading cause of potentially survivable deaths. Arguably, the success of the medical improvements during this war has served to maintain the lowest case fatality rate on record.**

Key Words: **Injury severity score, Autopsy, Combat, Iraq, Afghanistan.**

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There is a common opinion among military medical personnel returning from a second or third deployment to Iraq or Afghanistan that war wounds have increased in severity. Presumably, this would be a result of the change in enemy tactics. The insurgency war has intensified with increased sophistication and use of improvised explosive devices (IED). To counteract this, there is an ongoing effort to improve battlefield care through training, evidence-based clinical guidelines, and research. As opportunities to improve the outcome of wounded soldiers are identified, changes are implemented through the Joint Theater Trauma System.[1] Examples of this include advancements in point of injury care, such as, fielding of the Combat Application Tourniquet,[2,3] and hemostatic dressings.[4] In addition, weekly tri-continent trauma rounds are conducted to counteract the inevitable disconnect that occurs as wounded soldiers are rapidly moved to Germany and then the United States via the air evacuation chain. A number of predeployment training courses have been developed for medical personnel to hone their skills in trauma and critical care before deployment. Such courses include the Tactical Combat Casualty Care, Emergency War Surgery, and the Joint Forces Combat Trauma Management Course.[1] Additionally, ongoing collaborative efforts between the military and civilian level I trauma centers provide hands on training for deploying units.[5] In total, the DOD has issued 11 policies or clinical practice guidelines for combat care based on the ongoing analysis of the conflicts.[6]

To improve treatment, identify the equipment needs and develop training for military medical personnel in a combat theater, patterns of current combat deaths should be analyzed to direct health care interventions and research.[7] Analysis of civilian trauma deaths has been essential to the development of trauma systems, and assessing their performance over time.[8–10] Modern combat casualty care has evolved from investigation of casualty data from prior conflicts, and recently, a subset of deaths from Iraq and Afghanistan.[7,11–15]

As the enemy tactics in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) evolve, so must the

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medical care system. To evaluate how the evolving care given by military medical providers has changed outcomes, we compared an equal number of deaths from the beginning of the war with a more recent group. Our hypothesis was that as the use of IEDs has increased and injuries were more severe causing increased clinical challenges for patient care. Furthermore, through this analysis, we could evaluate potential areas of opportunity for improving patient care in a combat theater and drive combat casualty care research in a focused fashion.

METHODS

All US combatants from OIF and OEF whose remains are recovered and transported to Dover, DE where complete identification and forensic examination are performed by the Office of the Armed Forces Medical Examiner. Autopsy reports, photographs, treatment records, and radiograph reports are kept on file with the Armed Forces Medical Examiner System in Rockville, MD. Institutional Review Board approval for the study was provided by the US Army Institute of Surgical Research and the Armed Forces Institute of Pathology.

Cases were made up of combat fatalities, including those killed in action (KIA), or who died before reaching a medical treatment facility, and those who died of wounds (DOW), or died after arrival at a medical treatment facility.[16] A panel of surgical residents, a military trauma surgeon, civilian trauma surgeon, a trauma nurse, and trauma epidemiologist was assembled for this study. Forensic pathologists were available for consultation as needed. The panel used a consensus rule format.[17] The fatalities were classified as "potentially survivable" (PS) or "nonsurvivable" (NS) as described in a similar study conducted upon Special Operations fatalities.[7] Survivability was determined based on the injuries as identified at autopsy by the medical examiners. Treatment given was noted when available, but not used in the determination. Also, if multiple wounds were identified, each was evaluated individually for potential survivability. We erred on the side of inclusion as "potentially survivable" to facilitate speculation upon areas of improvement in the delivery of medical care in a combat theater. Therefore, if a casualty had three significant injuries that each alone would be survivable; the casualty was considered potentially survivable. All autopsies were coded for abbreviated injury scores (AIS) and injury severity score (ISS) using the 1998 version by a single person certified in AIS coding.

The cases were separated into two groups based on the date of fatality; group 1, from March 2003 to April 2004 and group 2, June 2006 to December 2006. All cases were examined for the mechanism of injury, ISS, age, branch of service (Army, Navy Air Force, or Marines), combat theater (OIF or OEF), KIA, DOW, medical examiner report, autopsy photographs, toxicology, and medical care received. Medical care documentation was usually limited, but evidence of surgical intervention could be seen in photos, and there were comments made by the forensic pathologist in regards to medical interventions. In-theater radiographs were not available, but the clinicians' impressions were sometimes found in the medical notes. Cases that required DNA identification or whose cause of death was labeled as "catastrophic" or "total body disruption" were recorded as nonsurvivable injuries and not reviewed further.

An indepth review was conducted on all other cases in a format similar to a surgical morbidity and mortality conference. This was performed to determine which cases sustained potentially survivable injuries. All patients were assumed to have immediate access to a US military level III medical treatment facility. These facilities are the highest level of care in a combat theater with advanced surgical capabilities, blood bank, radiology, and laboratory support. The potentially survivable cases were then used to evaluate areas of improvement or required research in combat casualty care.

Statistical Analysis

An unpaired Student's t test was used to analyze continuous variables. Dichotomous variables were compared using Fisher's exact test. Statistical significance was set at $p < 0.05$. Values in the text are reported as mean $\pm$ standard deviation (SD) unless otherwise indicated.

RESULTS

Of the 500 fatality records reviewed from March 2003 to April 2004 (group 1, 14 months), 486 were complete and met inclusion criteria for the study. Of the 497 fatality records reviewed from June 2006 to December 2006 (group 2, 7 months), 496 were complete and met inclusion criteria for the study. According to the Defense Manpower Data Center Statistical Information Analysis Division Website (http://siadapp.dmdc.osd.mil/personnel/CASUALTY/castop.htm), there were 1,066 combat deaths recorded during the time points chosen for the study. There were 997 cases on file with the Armed Forces Medical Examiner System, giving a record availability rate of 94%. Figure 1 shows the number of killed and wounded per month. Although the number of dead and wounded has roughly doubled during the time periods reviewed, there was no difference in the case fatality rate (CFR; 11.0 vs. 9.8, $p =$ NS).

Demographics and mechanism of injury data are found in Table 1. Overall, fatalities in group 1 were older than those in group 2, and had a lower injury severity score (50 ± 23 vs. 53 ± 22, $p < 0.04$) (Table 1). Group 1 had a lower percentage of deaths from explosives, and had higher percentages of deaths from aircraft crashes, gunshot wounds (GSW), and motor vehicle crashes (Table 1). There were 93 (19%) PS deaths in group 1 and 139 (28%) PS deaths in group 2 ($p < 0.001$) (Table 2), and group 2 had a higher ISS and greater number of injuries per patient above AIS 3 (Table 3). Table 2 also shows the percent of KIA and DOW for each group of PS fatalities. The percent of both KIA and DOW increased from group 1 to group 2. There was a difference between the groups within ISS intervals examined demonstrating lower

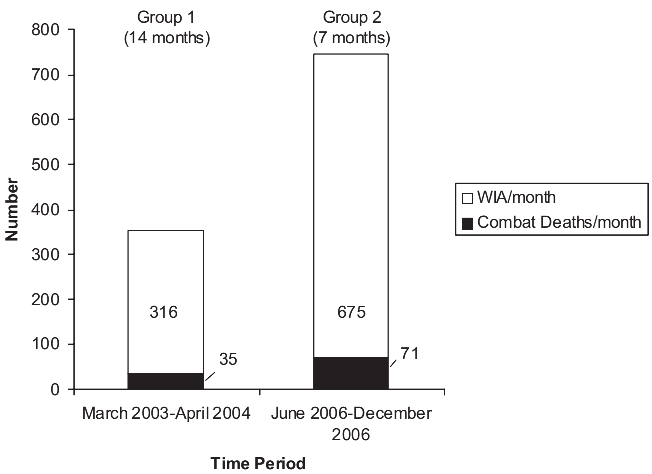

Fig. 1. *Number of wounded and killed per month for each group. From: Defense Manpower Data Center Statistical Information Analysis Division (made from data on publically available website: http://siadapp.dmdc.osd.mil/personnel/CASUALTY/castop.htm).*

Table 1 Demographic Data and Mechanisms of Injury for All Casualties in Group 1 and Group 2

	Group 1 (n = 486) (%)	Group 2 (n = 496) (%)
Age (yr)	26 ± 6.8	25 ± 6.4 ($p < 0.02$)
Gender (% male)	98	99
ISS-1998 (%75s)	50 ± 23 (40%)	53 ± 22 (43%) ($p < 0.04$)
Mechanism of injury		
Explosions*	275 (56)	381 (76) ($p < 0.001$)
Aircraft crash	55 (11)	0 (0) ($p < 0.001$)
Fall	4 (1)	1 (0.2)
Gunshot wound	148 (30)	118 (24) ($p < 0.004$)
MVC without IED	11 (2)	0 (0) ($p < 0.001$)
Other	3 (1)	1 (0.2)

* IEDs, rocket propelled grenades (RPGs), mortars, mines, bombs, grenades.
MVC indicates motor vehicle crash.

Table 2 Distribution of KIA and DOW Among the PS Deaths by Group

	Group 1		Group 2	
	Total Number (% Total)	PS (% Total)	Total Number (% Total)	PS (% Total)
All deaths	486	93 (19)	496	139 (28) ($p < 0.001$)
KIA	364 (75)	50 (14)	378 (76)	77 (20) ($p < 0.02$)
DOW	122 (25)	43 (35)	118 (24)	62 (53) ($p < 0.01$)

ISS among group 1 compared with group 2 ($p < 0.01$) (Fig. 2). When only PS fatalities were examined, group 1 had a lower percentage of deaths from explosions and had a higher percentage of PS deaths because of GSWs (Table 3).

Causes of death among the PS in each group are presented in Table 4. The most prevalent cause of death for both groups was hemorrhage (87% vs. 83%). Specifically, noncompressible, or torso, hemorrhage was most common fol-

Table 3 Demographic Data and Mechanisms of Injury for Potentially Survivable Casualties in Group 1 and Group 2

	PS	
	Group 1 (n = 93) (%)	Group 2 (n = 139) (%)
Age (yr)	26 ± 7	25 ± 6
Gender (% male)	96	100 ($p < 0.03$)
ISS-1998	27 ± 14	37 ± 16 ($p < 0.001$)
Mean number of AIS >3	1.1 ± .79	1.5 ± 2.1 ($p < 0.001$)
Mechanism of injury		
Explosions*	52 (56)	111 (80) ($p < 0.001$)
Aircraft crash	1 (1)	0 (0)
Fall	0 (0)	0 (0)
Gunshot wound	40 (43)	31 (22) ($p < 0.001$)
MVC without IED	1 (1)	0 (0)
Other	0 (0)	1 (0.7)

* IEDs, rocket propelled grenades (RPGs), mortars, mines, bombs, grenades.
MVC indicates motor vehicle crash.

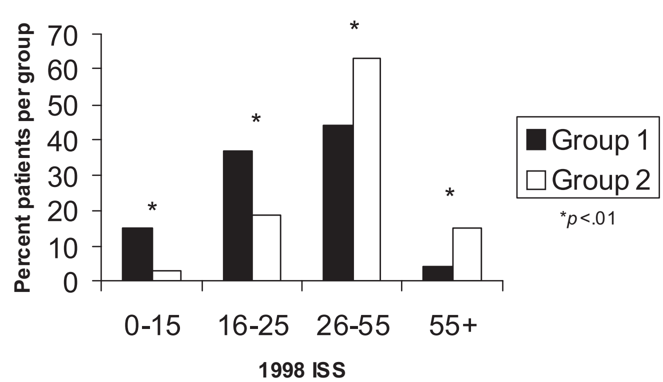

Fig. 2. *Distribution of injury severity scores for potentially survivable casualties.*

Table 4 Causes of Death Among Potentially Survivable Casualties

Cause of Death*	Group 1 (n = 93) (% Total of PS)	Group 2 (n = 139) (% Total of PS)
CNS	12 (13)	8 (6)
Head	11 (12)	6 (4) ($p < 0.04$)
Neck	1 (1)	0 (0)
Spinal cord	1 (1)	3 (2)
Hemorrhage	81 (87)	116 (83)
Tourniquetable (ext)	31 (33)	46 (33)
Noncompressible (torso)	47 (51)	68 (49)
Nontourniquetable (ax/neck/groin)	19 (20)	29 (21)
Airway	14 (15)	14 (10)
Sepsis/MSOF	2 (2)	9 (6)
Total causes of death identified	219	299

* Casualties could have 1 or more cause of death.
MSOF indicates multisystem organ failure.

lowed by "tourniquetable" or extremity hemorrhage, and "nontourniquetable but compressible" or axillary, neck, or groin hemorrhage. Only in the "head" subset of the central nervous system cause of death was there a significant decrease from 12% to 4% ($p < 0.04$). There was no difference in either group in regards to the percent of PS deaths among the Army and the Marines (data not shown).

To evaluate the use of the Combat Application Tourniquet, we isolated those PS fatalities caused by extremity injuries by evaluating those with an AIS ≥4 for extremity region, and excluding those with an AIS >4 in all other body regions. The results are shown in Table 5. The chest and abdomen AIS were significantly lower in group 1 (0 vs. 0.8 ± 1.3, $p < 0.05$ and 0.3 ± 0.73 vs. 1.3 ± 1.2, $p < 0.02$, respectively). In group 2, no deaths from extremity wounds were caused by a GSW and there are more multiple severe extremity injuries. Also, the number of tourniquets used increased.

DISCUSSION

Caring for combat casualties presents health care providers with challenges unique to the military. The ferocity of modern weaponry and the change in enemy operation tempo and tactics are not comparable with the civilian sector. Medics, the health care provider on the front lines, may have to deal with numerous casualties, incoming fire or may be incapacitated themselves. Furthermore, the surgical treatment facilities may, at times, operate under a massive casualty situation (MASCAL) where triage of the wounded is needed to save as many lives and resources as possible. Our analysis presents an opportunity to act upon the challenges encountered in combat care. The standard used was survivability of individual wounds under optimal level III surgical care, the highest standard available in theater. This dependent variable, however, may not be a just means by which to measure care in a combat setting. It is not possible to quantify the additive effects of multiple potentially survivable, yet severe, wounds that are commonly encountered, combined with the hostile tactical situation.

Our data show a difference in the percent PS between each group (19% vs. 28%, $p < 0.001$), and is higher than the civilian literature reports of 8% to 13%,[18–20] and our previous report of Special Operations deaths of 15%.[7] It is virtually impossible to compare our set of combat casualties with the civilian literature. This is primarily because of the differences in the mechanism of injury, as explosions became the predominate mechanism of injury. In our entire study population, 83% of deaths resulted from penetrating injury, whereas the civilian studies quote 84% to 90% of deaths from blunt injury. Another likely reason for the differences in potentially survivable fatalities is our methodology. Again, we erred on the side of inclusion, so as to identify areas of improvement and research opportunities in combat health care.

The main cause of death among the PS in both patient cohorts was hemorrhage that contributed to 85% of the deaths. This was similar (82%) to the results of the Special Operations death previously studied.[7] In studies of civilian patients mortality from truncal hemorrhage is the leading cause of death.[21]

The difference in mechanism of injury (Table 1) between the groups is a reflection of the change in the enemy forces and tactics during the time course studied. The early conflict was more of a traditional war with most injuries resulting from small arms wounds, to the present insurgency characterized by ambushes, IEDs, and other explosive devices.[1] IEDs now contain more explosive power, produce more and deadlier fragmentation, and use more fuel to increase the size of the fire ball produced. Explosive mechanisms increased from 56% to 76% ($p < 0.001$), and GSWs decreased from 30% to 24% ($p < 0.004$). The increased ISS among the PS in group 2 (Table 3) suggest that as personnel and vehicle armor improves, so do the weapons used against our fighting forces. It could also suggest that it takes a more severe injury now to cause a fatality, which would be reflective of improved medical care. When the ISS is broken down to the individual AIS categories, there are more AIS >3 per death in group 2 (Table 3). The ISS and AIS >3 together suggest that not only the injuries in group 2 are more severe, but there are also just more injuries for medical personnel to deal with (1.1 ± 0.79 vs. 1.5 ± 2.1 per person, $p < 0.001$).

Table 2 shows the percentage of KIA and DOW fatalities labeled as potentially survivable. The percent increase in DOW between group 1 and group 2 (35% vs. 53%, $p < 0.01$)

Table 5 **Differences in Fatalities Caused by Extremity Injuries Among Potentially Survivable Deaths (Excluded AIS of 4, 5, 6 From Other Body Regions)**

	Group 1	Group 2
N	14 (15%)	13 (9%) (p = 0.07)
ISS	16 ± 5	20 ± 6
Mechanism		
Explosion	71%	100% (p = 0.09)
GSW	29%	0% (p = 0.09)
AIS		
Chest	0	0.8 ± 1.3 ($p < 0.05$)
Abd	0.3 ± 0.73	1.3 ± 1.2 ($p < 0.02$)
No. extremity injured	20	23
Single limb (% of N)	8 (57%)	4 (31%)
Multiple limbs	6 (43%)	9 (69%)
Extremity injuries/pt	1.4	1.8
No. of patients with Tourniquets (% of N)	3 (21%)	6 (46%)
Total number tourniquets	6	12
No. tourniquets/pt	0.43	0.92
No. tourniquets/limb injured	0.30	0.52
No. injured from GSW	4 (29%)	0
Single limb	3	NA
Two limbs	1	NA
No. tourniquets	0	NA

may reflect improved transport of casualties from the battlefield to a medical treatment facility. However, the percent of PS KIA also increased (14% vs. 20%, $p < 0.02$), but to a lesser degree. This would reflect a point made previously; combat medics may be dealing with numerous casualties at a time, and immediate evacuation may not always be feasible given mission requirements and enemy activity.

The casualties evaluated in group 1 were sustained during a 14-month period, whereas the casualties from group 2 were sustained during a 7-month period. The number of wounded and killed was similar between the two groups, but the deaths per month doubled from 35 to 71 (Fig. 1). This shows that the war has essentially become twice as violent or deadly. However, during that time, the CFR among US casualties did not change. The stability of the CFR (11.0 vs. 9.8, p = NS), although the injuries become more severe, could be partially attributed to the adaptation and improvement of combat medical care.

One critical aspect that may improve outcomes in theater is rapid transport from the point of injury to a facility with surgical capabilities. However, rapid evacuation can be hindered by mission requirements, terrain, weather, and ongoing enemy activity, which will always be an issue when working within a combat zone.[7] Decreased transport time would be identified as an area of improvement in any trauma system, civilian, or military. Our data set once again shows that the leading cause of PS deaths in OIF/OEF is torso, or noncompressible, bleeding. By providing medics with some of the tools of damage control resuscitation,[22,23] interventions directed by these data could be implemented earlier.

Prevention is a way of decreasing not only deaths, but all injuries. Improvements in body and vehicle armor have been made, and will continue. However, improvements can only go so far before they begin to hinder performance. If standard body armor is made to cover arms and legs, the soldier has now lost mobility and will not be as effective in a fire fight. A better means by which to identify IEDs or better convoy tactics could decrease injuries as well. However, any suggestions from the medical community in regards to tactical combat maneuvering are purely speculative.

As this is a retrospective review, there are limitations inherent to the study. There is little recorded information on point of injury care, unless it was obvious in a photograph (i.e., tourniquets still in place). However, the absence of a tourniquet did not mean one was not placed, and its presence did not always mean it was effective. Speculations were made as to the position of a tourniquet, but it is possible that they may have been displaced during transport. The data in Table 5 attempt to evaluate the use of tourniquets in fatalities caused by extremity injury. The numbers are small, but these data suggest that the tourniquet usage has increased and exsanguinations from isolated extremity GSWs are no longer the problem that they presented at the outset of the conflict.[24]

At first glance the data may be viewed as disappointing given the fact that despite all the work performed on improving medical care in theater, causes of death among PS fatalities have not changed. However, it needs to be restated that only deaths were reviewed, not survivors. Data on injury patterns among survivors would be needed to provide a complete picture of the change in injury distribution. The focus of this study was to identify causes of potentially survivable death among our soldiers to focus efforts on improvement. The number one cause of potentially survivable deaths in combat continues to be hemorrhage. Extremity and compressible hemorrhage (axilla, neck, or groin) are two of the three types of hemorrhage evaluated. Controlling these types of hemorrhages is addressed by effective commercial tourniquets and topical hemostatic agents like the widely available hemostatic dressings.[4,24] Continued training and use with these products is warranted. The third type of hemorrhage, and the most challenging type in our study, was noncompressible or torso hemorrhage. There needs to be continued research and clinical practice focusing on intravenous hemostatic adjuncts and damage control resuscitation.[23] Providing prehospital medics with these products may allow the initiation of intravenous hemorrhage control earlier after injury.

In this study, we have confirmed the opinion of medical personnel; injuries sustained in Operation Iraqi Freedom and Operation Enduring Freedom have increased not only in severity, but in number, making it more of a challenge to care for the severely wounded. The time period for group 1 is twice as long as that of group 2, but the number of deaths is the same, which means the deaths per month doubled. However, the CFRs are unchanged. Arguably, this is because of the improvements in combat casualty care through experience, training, research, and implementation of effective clinical practice guidelines.

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DISCUSSION

Dr. Martin A. Schreiber (Department of Surgery, Section of Trauma and Critical Care, Oregon Health & Science University, Portland, OR): In this very impressive, landmark autopsy study the authors have made several important findings some of which are old and some of which are new. They have found that noncompressible hemorrhage is the most common cause of potentially survivable death. They have also found that there has been an increase in deaths because of IEDs and there has been an increase in the number and severity of injuries per patient. They conclude that the mechanisms of injury have become more powerful resulting in greater injury severity.

I have several questions and comments for the authors:

1. The authors state that the documentation of medical care delivered was limited. How did the board of experts determine preventability without documentation of medical care? Was it solely based on severity of wounds? Was TRISS methodology or some other methodology used to provide objectivity to the analysis?
2. The authors excluded 12 patients from their study who had an autopsy. What was the basis for exclusion? Did the board establish inclusion and exclusion criteria prospectively or after the study had started.
3. The authors conclude that injury severity has increased and wounding patterns have become more severe. Their data show that overall ISS in fatalities has increased to 53 from 50. Although this is statistically significant, it does not seem to be clinically relevant.
4. This raises the issue of the statistical analysis used. In their article, they state that they used a paired *t* test to compare means. This is not an appropriate test as they do not have paired values to compare. What test did they use and was their statistical analysis performed properly?
5. Although the results from this study are fascinating, they must be interpreted with caution. The patients analyzed in this study were all fatalities and they represent only about 10% of all casualties. To do this analysis correctly it would be necessary to repeat this analysis on all casualties. The fact that the overall case fatality rate has not changed during the war argues against the authors conclusions although it is impossible to determine the relative contributions of injury severity and the quality of medical care delivered.

Dr. Joseph F. Kelly (US Army Institute of Surgical Research, Fort Sam Houston, TX): Thank you for your comments and questions. TRISS methodology was not used. We determined if each individual wound was potentially survivable based on the anatomy and severity of the injury. The sum of the injuries and their combined impact on survivability were not taken into account. The amount of medical care was not taken into account; there were KIAs and DOWs among both the survivable and nonsurvivable deaths. The inclusion criteria were that the injuries had to occur during combat operations in Iraq or Afghanistan. Ten of the 12 cases excluded were excluded because of incomplete records, usually the absence of photos, which sometimes occurred when the autopsies were not performed by mortuary affairs at Dover Air Force Base. The other two were excluded because the injuries sustained did not occur during combat operations.

Your point on the ISS increasing from 50 to 53 being clinically irrelevant is well made. The mean ISS of each group is high because of the number of fatalities coded with and ISS equal to 75. This is the reason why we broke the groups down into potentially survivable (PS) and nonsurvivable (NS). We were able to show a difference in the ISS of this subset that is more clinically relevant. The test performed was an unpaired *t* test.

I agree with your last point. It would be very helpful to evaluate all casualties. This would enable us to investigate the survivability of specific injuries, and which interventions were beneficial. However, this type of analysis on trauma deaths has been the mainstay of trauma system development, analysis, and improvement for decades. It also enables us to identify areas of improvement in medical combat care.