pulmonary system, and solid abdominal organs had the strongest association with mortality. Severity of pelvic fracture seemed to have an influence on mortality when controlling for large vessel and brain injury. In addition, pelvic fractures secondary to direct combat (ie, blast-related blunt, penetrating) were significantly more lethal than were mechanisms analogous to civilian trauma.

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 AUG 2012	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Factors Associated With Mortality in Combat-related Pelvic Fractures	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Davis J. M., Stinner D. J., Bailey J. R., Aden J. K., Hsu J. R.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**6**	

Table 5

Mortality Rate and Associated Injuries in Stable and Unstable Combat-related Pelvic Fracture[a]

Fracture Type	Large Vessel Injury	Anatomic Brain Injury	Unstable Fractures	No. of Survivors	No. of Nonsurvivors	Mortality (%)	*P* Value
Unstable[b]	N	N	Y	2	11	84.62	<0.05
Stable[c]	N	N	N	8	6	42.86	<0.05

N = no, Y = yes
[a] Controlling for extrapelvic injuries with 100% mortality
[b] Tile types B and C, and unable to classify
[c] Tile type A

study, both demonstrate an association between fracture classification and mortality. This is supported by previous data from studies in which pelvic fractures were categorized according to either the Tile classification[16,17] or the Young-Burgess classification.[22] Two recent reviews of trauma patients admitted to level I trauma centers demonstrated that the presence of a pelvic fracture alone, regardless of type, was an independent risk factor for mortality.[23,24]

The cause of death in patients who sustain pelvic fractures is frequently multifactorial, whether it be major hemorrhage from an associated injury—which has been implicated as a cause of death in ≤49% of patients with a pelvic fracture in the civilian literature,[25,26]—or by the combination of shock at presentation and associated head injuries.[23] Although some studies have failed to find an association between pelvic fracture classification and mortality,[26,27] almost all studies assessing mortality rates have shown that associated injuries contribute to the overall mortality rate.[1,9-12,21,23,25-30] Associated injuries, specifically moderate to severe chest and head injuries, seem to be more common in nonsurvivors of pelvic trauma than in survivors.[1,25,27,28] The subset analysis of our findings clearly shows that, even in the presence of unstable fractures, when controlling for large-vessel and anatomic head injuries, the mortality rate remains high but is reduced.

An unexpected result in this study is the lack of difference in mortality in patients who sustained blunt injuries to the pelvis compared with penetrating injuries. In the civilian population, patients admitted to trauma centers with a pelvic fracture frequently sustained blunt injury as a result of an MVA or a fall.[1,3-8] The main cause of injury in our study population was not MVAs and falls but rather explosions and IEDs. A plausible explanation is that so many of those included in this study sustained blunt injuries as the result of a blast mechanism. Therefore, we performed an additional analysis comparing conventional mechanisms of injury (eg, MVA, falls) that caused blunt injury to the pelvis, blast mechanisms that caused blunt injuries to the pelvis, and all penetrating injuries. Even in the combat setting, conventional blunt injuries to the pelvis resulted in a significantly lower mortality rate (4 of 7 [57%]; $P < 0.05$), albeit at a rate that is higher than that seen in the civilian population. Tertiary blast injury can be very high energy, with rates of mortality similar to those of penetrating pelvic injuries.

Our study has several weaknesses. First, it was retrospective in nature and has the inherent shortcomings of such studies. In particular, much of the available civilian literature uses admission criteria when predicting mortality rates. Because of the small number of survivors in this study and the lack of data available from the initial point of care, we were able to perform analyses using only gross data pertaining to documented associated injuries.

The year 2008 was chosen because of completeness of medical records and autopsy data as well as availability of electronic radiographs. However, radiographs were not available for some patients, which resulted in exclusion of eight patients from group 2. In addition, inclusion of survivors in group 1 was made based on the data within the JTTR; this is problematic because patients who survived with pelvic fracture may not have been captured by the registry.

Finally, although several studies have successfully applied the Young-Burgess classification to determine associated mortality risk in civilian trauma patients,[22,30] the injury patterns seen in the patient population we studied were such that most patients either did not fit into the Young-Burgess classification or had a complex injury that made specific analysis difficult with relation to this fracture classification.

Summary

In our study, associated injuries to large vessels, the brain, the cardio-

Table 3

Combined Results by Mechanism of Injury to the Individual Person and to the Pelvis

MOI Person (Pelvis)	Survivors (group 1)	Nonsurvivors (group 2)	Mortality (%)	*P* Value
Blast (blunt)	2	27	93.10	<0.05
Conventional (blunt)	3	4	57.14	<0.05
Penetrating	5	60	92.31	<0.05

MOI = mechanism of injury

Table 4

Outcomes Following Combat-related Pelvic Fracture by Associated Injuries

Associated Injury	Survivors (n = 10)	Nonsurvivors (n = 91)	Mortality With Injury (%)	Mortality Without Injury (%)	*P* Value
Large pelvic vessel	0	17	100.00	88.10	0.20
Genitourinary	2	39	95.12	86.67	0.19
Large vessel	0	40	100.00	83.61	<0.01
Extremity	7	64	90.14	90.00	1.00
Traumatic amputation	2	29	93.55	88.57	0.72
Spine fracture	1	36	97.30	85.94	0.09
Spinal cord	0	16	100.00	88.24	0.36
Anatomic brain	0	48	100.00	81.13	0.001
Cardiopulmonary	1	60	98.36	77.50	<0.001
Solid organ (abdominal)	2	58	96.67	80.49	0.01
Hollow viscous	4	37	90.24	90.00	1.00

Associated Injuries and Mortality

Most of the patients studied had polytrauma, with many associated injuries, as demonstrated by the high Injury Severity Score seen in group 1 (average, 27.5; range, 16–59). Significant predictors of mortality included large-vessel injury, anatomic brain injury, cardiopulmonary injury, and solid organ abdominal injury ($P < 0.05$) (Table 4).

Subset Analysis

To identify injury patterns that were associated with a lower mortality rate, we compared stable (Tile type A) and unstable (Tile types B, C, and unable to classify) pelvic ring injuries, controlling for patients with statistically significant nonorthopaedic extrapelvic injuries that were associated with a 100% mortality rate (eg, large vessel, anatomic brain). This analysis demonstrated a significantly lower mortality rate in patients with stable pelvic fractures than in patients with unstable pelvic fractures (6 of 14 [43%] and 11 of 13 [85%], respectively; $P < 0.05$) (Table 5).

Discussion

A simple comparison of the numbers in each of the two study groups yields a 9.9% (10/101) survival rate following CRPF. This is similar to what has been described in the civilian trauma population in the past 16 years, with studies indicating that the typical mortality rate for patients admitted to level I trauma centers with pelvic fracture is between 3% and 20%.[1,2,7,13-17] This statistic alone clearly demonstrates the severity of pelvic fracture when sustained on the battlefield.

Several other key results in our study mirrored reported data in the civilian literature. First, rotationally stable fracture patterns (ie, Tile type A) were found to be more common in survivors than nonsurvivors (8 of 10 [80%] and 24 of 91 [27%], respectively; $P = 0.001$). However, Tile type A fractures were associated with a 75% mortality rate. Severity of the pelvic fracture was associated with mortality when controlling for large-vessel and head injury. Similarly, in a comparison of 1,248 patients admitted to a civilian level I trauma center, Manson et al[21] showed that stable fracture patterns were associated with a lower mortality rate than were unstable fracture patterns (7.9% and 11.5%, respectively; $P < 0.05$). Although the mortality rates reported by Manson et al[21] are much lower than those we report in this

one surviving service member with Tile type C pelvic ring injury (ie, vertically and rotationally unstable). Type C injury was associated with a 98% mortality rate (50 of 51; $P < 0.01$). Although not statistically significant, there were no Tile type B (ie, rotational unstable and vertically stable) fractures in group 1 ($P = 0.35$). Most fractures could not be classified into an appropriate Young-Burgess category because of incomplete radiographic evaluation or the complexity of the fracture pattern.

Mechanism of Injury and Mortality

Results of reported mechanism of injury to the person as a whole and the direct mechanism to the pelvis are summarized in Table 3. IED blast was a significantly more lethal reported mechanism of injury than was MVA (68 of 70 [97.1%] and 4 of 7 [57.1%], respectively; $P = 0.001$). In terms of direct mechanism of injury to the pelvis, blunt and penetrating injuries carried similar associated mortality rates (31 of 36 [86.1%] and 60 of 65 [92.3%], respectively; $P = 0.32$). However, conventional mechanisms of injury (eg, MVA, fall) that caused blunt injuries to the pelvis resulted in a lower associated mortality rate (4 of 7 [57.1%]) than did blast mechanisms that caused blunt injuries to the pelvis (27 of 29 [93.1%]) and all penetrating mechanisms (60 of 65 [92.3%]) ($P < 0.01$) (Tables 1 and 3).

Table 1

Patient Demographics and Mechanism of Injury in Combat-related Pelvic Fracture

Characteristics	Survivors (group 1)	Nonsurvivors (group 2)
No. of patients	10	91
Average age in years (range)	28.7 (21–45)	27.4 (19–45)
Average ISS (range)	27.5 (16–59)	75 (75–75)
Mechanism of injury		
Explosion (non-IED)	2	8
MVA	3	4
GSW	3	14
IED	2	68
Other	2	1
Type of injury to pelvis		
Blunt	5	31
Penetrating	5	60

GSW = gunshot wound, IED = improvised explosive device, ISS = Injury Severity Score, MVA = motor vehicle accident

Table 2

Results by Pelvic Fracture Classification

Classification	Survivors (group 1)	Nonsurvivors (group 2)	Mortality (%)	*P* Value
Tile				
A	8	24	75.00	0.0014
B	0	13	100.00	0.3524
C	1	51	98.04	0.0079
Unable to classify	1	3	75.00	0.3454
Young-Burgess				
APC I	1	1	50.00	0.1891
APC II	1	5	83.33	0.4740
APC III	0	6	100.00	1.0000
APC unspecified	0	8	100.00	1.0000
LC I	1	2	66.67	0.2710
LC II	0	2	100.00	1.0000
LC III	0	1	100.00	1.0000
VS	1	11	91.67	1.0000
Unable to classify	6	30	NA	NA
Combination	0	25	100.00	0.0634

APC = anterior-posterior compression, LC = lateral compression, NA = not applicable, VS = vertical shear

tures can provide insight that may lead to improved overall survival. The purpose of this study was to identify the factors that resulted in patient mortality following combat-related pelvic fracture (CRPF).

Methods

We searched two databases to identify US service members who sustained CRPFs during OEF and OIF from January 1 through December 31, 2008. We first searched the Joint Theater Trauma Registry (JTTR), using International Classification of Diseases (ICD)-9 codes relevant to pelvic fracture to identify persons who survived CRPFs (group 1). The second database searched was an existing database created from data obtained through a prior search of the Armed Forces Medical Examiner System (AFMES) to identify all nonsurvivors with autopsy-documented pelvic fracture (group 2).[20]

Survivor cohort data were collected using electronic medical records and radiographs. Nonsurvivor cohort data were collected using autopsy reports, electronic radiographs, and comprehensive autopsy photographs. Patients for whom we could not confirm the presence of a pelvic fracture (ie, patient radiographs were not available for review) were excluded.

Pertinent data were extracted for analysis from both groups, including mechanism of injury to the person as a whole (ie, improvised explosive device [IED], non-IED explosion, MVA, gunshot wound, other), type of direct injury to the pelvis (blunt versus penetrating), pelvic fracture classification (Tile or Young-Burgess), and other associated injuries. For purposes of categorizing associated injuries, large-vessel injuries included all extrapelvic large-vessel injuries, whereas pelvic vessel injuries included all intrapelvic vessel injuries. Anatomic brain injury was defined as a nonsurvivable head injury. Instances of a combined mechanism of injury to the person as a whole (eg, MVA plus IED) were counted separately; however, the mechanism of injury to the pelvis, whether blunt or penetrating, was determined based on available data reviewed. To attempt to mimic mortality rates between civilian-type pelvic injuries (conventional blunt [ie, MVA, crush]) and combat-type pelvic injuries (ie, blast-related blunt, penetrating), we determined and compared mortality rates for each group. All of the fractures were classified by a fellowship-trained orthopaedic trauma surgeon (J.R.H.).

Statistical Analysis

Mortality rates were determined for each patient based on mechanism of injury, type of injury to the pelvis, fracture classification, and associated injuries. A chi-square analysis was used to compare expected frequencies of each factor. In cases in which frequencies were <5, the Fisher exact test was used to determine *P* values. Variables with a *P* value <0.05 were deemed to be significant. Classification trees were designed to establish combinatory modes of injury. Factors chosen for classification were done after the fact, based on clinical relevance and significance.

Results

The JTTR search from January 1 through December 31, 2008, identified 12 service members who survived combat-related injuries with an ICD-9 diagnosis of pelvic fracture. Two were excluded from the study because of incorrect diagnoses, leaving a total of 10 patients in group 1 (survivors).

The search of the AFMES database during the same period identified a total of 260 service members who were identified as killed in action and 90 who died of wounds. Of those 350 service members, 104 were identified through the AFMES database as having pelvic fracture found at autopsy. Thirteen were excluded from the study group, 8 because of unavailable electronic radiographs to confirm the diagnosis and 5 because of incorrect diagnoses, leaving a total of 91 patients included in group 2. Thus, the overall mortality rate for a service member who sustained a CRPF was 90.1% (91 of 101), with a survival rate of 9.9%. Demographic data are listed in Table 1.

Fracture Type and Mortality

Although Tile type A (ie, stable) fractures were more common in group 1 (8 of 10 [80%]) than in group 2 (24 of 91 [26%]), they were associated with a 75% mortality rate (24 of 32; $P = 0.001$) (Table 2). There was only

Dr. Stinner or an immediate family member serves as a board member, owner, officer, or committee member of the Society of Military Orthopaedic Surgeons and the Orthopaedic Trauma Association. Dr. Hsu or an immediate family member has received research or institutional support from The Geneva Foundation, Combat Casualty Care Research Program, and the Major Extremity Trauma Research Consortium (METRC) and serves as a board member, owner, officer, or committee member of the Society of Military Orthopaedic Surgeons, the Limb Lengthening and Reconstruction Society, the Orthopaedic Trauma Association, METRC, the Skeletal Trauma Research Consortium, and the American Academy of Orthopaedic Surgeons. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Davis, Dr. Bailey, and Dr. Aden.

Factors Associated With Mortality in Combat-related Pelvic Fractures

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Abstract

Pelvic fractures were sustained by ≥26% of service members who died during Operation Enduring Freedom and Operation Iraqi Freedom in 2008. To determine factors associated with patient mortality following combat-related pelvic fracture (CRPF), the Joint Theater Trauma Registry database was searched to identify service members who survived CRPF sustained in the year 2008 (group 1), and the Armed Forces Medical Examiner System was searched to identify nonsurvivors of such trauma in the same year (group 2). Stable pelvic ring injuries were associated with a lower mortality rate than were unstable injuries when controlling for large-vessel and anatomic brain injuries (43% and 85%, respectively; $P < 0.05$). Associated injuries that were significant predictors of mortality included large-vessel, anatomic brain, cardiopulmonary, and solid organ abdominal ($P < 0.05$). Compared with a similar cohort of nonsurvivors, persons who survive CRPF have less severe pelvic fractures and associated injuries. In addition, pelvic fractures secondary to direct combat (ie, blast-related blunt injury, penetrating injury) were significantly more lethal than were those caused by mechanisms analogous to civilian trauma.

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The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army, Navy or the Department of Defense.

J Am Acad Orthop Surg 2012; 20(suppl 1):S7-S12

http://dx.doi.org/10.5435/JAAOS-20-08-S7

Pelvic fractures in civilian trauma account for 3% to 8% of all skeletal trauma injuries.[1-3] The most common causes of these fractures are motor vehicle accidents (MVAs), motorcycle accidents, and other high-energy mechanisms of injury.[1,3-8] Pelvic fractures are often associated with hemodynamic instability, chest trauma, head injuries, liver or spleen injuries, and long bone fractures.[1,9-11] Multiple studies have shown an association between mortality rates and the severity of pelvic fractures and associated injuries.[1,9,11,12] Civilian mortality rates in patients with pelvic ring injuries range from 3% to 20%.[1,2,7,13-17]

Compared with civilian trauma, battlefield wounds are often the result of higher-energy mechanisms and are often coupled with extensive associated injuries.[18,19] A recent review of wartime mortality data confirmed these concerns regarding military trauma. The report indicated that pelvic fractures occurred in ≥26% of service members who died during Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) in 2008.[20] However, data were isolated to military personnel who did not survive their injuries.

Knowledge of the fracture patterns, mechanisms of injury, associated injuries, and early interventions of those who survive combat-related injuries with associated pelvic frac-