

Mechanism of Injury Predicts Patient Mortality and Impairment After Blunt Trauma

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Submitted for publication January 7, 2008

Background. Different mechanisms of injury (MOI), such as motor vehicle crashes, falls, or pedestrians struck by motor vehicle impart varying degrees of force and energy transfer that may impact outcomes. This study analyzed the independent relationship between MOI and mortality and functional outcomes following blunt trauma among adults.

Materials and methods. Retrospective review of blunt trauma patients 15 y and older in the National Trauma Data Bank from 2001 to 2005. Primary outcome measures were mortality and presence of functional deficit in speech, walking, or feeding at discharge. MOI categories, identified by ICD-9 E codes, were motor vehicle crash, pedestrian struck by motor vehicle, motorcycle crash, falls at same level and from any height, and bicycle crash. A multiple regression analysis was performed adjusting for patient demographics and injury severity variables with motor vehicle crash as the reference mechanism group.

Results. Over the period studied, 515,464 patients met inclusion criteria. Mean Injury Severity Score (16.9), mortality rate (11%), and extremity injury (20%) were highest among pedestrians struck by motor vehicle, and head injury (16%) highest for motorcyclists. Overall, 52% had impaired ambulation, 16% impaired feeding, and 10% impaired speech. Adjusted odds of death, impaired walking, and impaired speaking were highest for pedestrians struck by motor vehicle, and impaired feeding highest for motorcyclists.

Conclusion. After adjusting for confounders, MOI was found to independently predict mortality and functional impairment at hospital discharge. Current injury assessment models could be greatly enhanced by

including MOI, and we propose routine adjustment for injury mechanism in trauma outcomes research. © 2008 Elsevier Inc. All rights reserved.

Key Words: trauma; mechanism of injury; functional outcomes; injury severity; mortality.

INTRODUCTION

Trauma has typically been categorized injury in 2 broad types, blunt or penetrating. Each “type” of trauma has different epidemiology patterns, management paradigms, and outcome assessment methodologies. In penetrating trauma, injury is usually focused on the areas directly affected by the penetrating object. The effect of blunt traumatic injury may be more diffuse, and different blunt trauma “mechanisms” impart varying degrees of force and energy transfer [1].

Blunt trauma occurs in more than 80% of trauma patients [2], and can be subdivided by mechanisms of injury (MOI), which include motor vehicle crash (MVC), falls, pedestrian struck by motor vehicles, bicycle crashes, motor cycle crashes, and various other mechanisms. When added to the different patterns of velocity and energy transfer noted above, stratifying by blunt trauma mechanisms is likely necessary to study outcomes. For example, forces inflicted on a pedestrian struck by a motor vehicle may be much greater than an occupant in a MVC, in which the victim has some protection.

Mechanism of injury has proven to be useful in field triage. When used in combination with other indices, MOI has limited under-triage and over-triage of trauma patients at the injury scene [3–5]. Similarly, certain mechanisms are highly associated with specific injuries. For example, falls from a height typically result in calcaneal fractures and motor cycle crashes are highly

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TABLE 1

E Codes Included in Each Mechanism of Injury

Mechanism of injury	E codes included
Motor vehicle crash	E810–E819 (.0, .1)
Pedestrians struck	E810–E819 (.7)
Bicycle	E810–E819 (.6)
Motorcycle	E810–E819 (.2, .3)
Falls from any height	E880 (.0, .1, .9), E881 (.0, .1), E882, E883 (.0, .1, .2, .9), E884 (.0, .1)
Falls at same level	E880.0 to E886.9, E888, E957(0–.9), E968.1, E987 (.0–.9) excluding those defined in “falls from any height” above

Note. Based on CDC recommended framework for presenting injury mortality data.

associated with pelvic fractures [6]. Based on such research, MOI appears to be a useful variable to consider in trauma care.

However, little is known about the independent relationship between MOI and trauma outcomes among blunt trauma patients. The purpose of this study was to identify the association between mechanism of injury and outcomes following injury, specifically mortality and functional outcomes. We hypothesized that adult patients who suffer otherwise similar and equivalent blunt injuries may have disparate outcomes based on the mechanism by which they sustain their injury.

METHODS**Study Design**

This was a retrospective review of patient records in the National Trauma Data Bank (NTDB) version 6.1, which includes patients from the years 2001 to 2005. The NTDB is the largest repository of

adult trauma data available for study in the United States. It is managed by the American College of Surgeons and collects cases from approximately 700 trauma centers. This study was reviewed by the Johns Hopkins University School of Medicine Institutional Review Board and approved for exempt status.

Participant Selection

Patients above the age of 14 y (the minimum age of admission at our adult trauma center) who suffered moderate to severe blunt trauma were selected for this study. Trauma severity was determined using the Injury Severity Score (ISS) [7], and patients with a score ≥ 9 met the inclusion criteria. Patients with penetrating trauma or burns were excluded from this study.

Outcome Measures

The primary outcome measures with respect to mechanism of injury were mortality and presence of a functional deficit in speech, walking, or feeding at the time of hospital discharge. Functional outcomes were measured using a modification of the Functional Independence Measure (FIM) [8] score in the 3 domains. Each domain had a FIM score range from 1 to 4 (1 = poorest function/completely dependent; 4 = normal function/no dependence). Patient outcomes were categorized as No Deficit (FIM = 4) or Presence of Deficit (FIM <4) in each of the 3 domains. As data reporting to the NTDB is voluntary, several hospitals systematically did not report any functional outcome data. For this reason, only patients with complete functional outcome data were analyzed in this part of the study.

Primary Data Analysis

Patients were placed into MOI categories using International Classification of Diseases, Ninth Revision E codes [9], based on the Centers for Disease Control and Prevention's (CDC) recommended framework for injury and mortality data [10]. These categories included motor vehicle crash, pedestrian struck by motor vehicle, motor cycle crash, falls, bicycle crash; codes are listed in Table 1. Based on our hypothesis that velocity and energy transfer are a factor in trauma sustained and outcomes, we further stratified falls into: falls at the same level and falls from any height.

A multiple regression analysis was done to determine outcome differences based on MOI. Each injury mechanism category was

TABLE 2

Blunt Trauma Patient Demographics

Demographics	All patients (n = 515,464)	MVC (n = 241,111)	Pedestrian struck by MV (n = 35,632)	Motorcycle crashes (n = 36,403)	Bicycle (n = 16,569)	Falls at same level (n = 126,967)	Falls from any height (n = 57,782)
Men, %	69	63	69	88	84	65	78
Mean age, y	39	35	40	38	40	43	43
Race, %							
White	73	72	53	83	75	77	74
Black	13	13	24	9	11	12	13
Hispanic	9	10	16	5	10	7	9
Other	5	5	7	4	4	4	4
Insurance, %							
Commercial	43	54	35	55	45	23	37
Government	24	28	41	28	34	13	21
Uninsured	22	7	13	3	8	57	31
Other	11	11	11	12	12	6	9

MVC = motor vehicle crash; Pedestrian struck by MV = pedestrian struck by motor vehicle.

TABLE 3
Injury Severity Characteristics by Mechanism of Injury Group

Injury severity characteristics	All patients (<i>n</i> = 515,464)	MVC (<i>n</i> = 241,111)	Pedestrian struck by MV (<i>n</i> = 35,632)	Motorcycle crashes (<i>n</i> = 36,403)	Bicycle (<i>n</i> = 16,569)	Falls at same level (<i>n</i> = 126,967)	Falls from any height (<i>n</i> = 57,782)
ISS, mean ± SD	16.9 ± 6.25	18.4 ± 5.5	19.4 ± 6.08	18.5 ± 5.5	16.4 ± 4.6	13.8 ± 4.2	15.1 ± 4.15
RTS, mean ± SD	7.13 ± 0.9	7.07 ± 0.85	6.81 ± 0.95	7.08 ± 0.86	7.35 ± 0.85	7.52 ± 0.52	7.43 ± 0.6
Mortality, %	5.96	5.74	10.84	6.36	4.26	3.61	3.73
Ext injury, %	16	14	20	18	12	18	15
Head injury, %	13	13	14	16	11	11	11

MVC = motor vehicle crash; SD = standard deviation; Pedestrian struck by MV = pedestrian struck by motor vehicle.

compared with MVC, which was used as the reference group. Patients were adjusted for demographic and injury severity variables known to be independently associated with outcomes after trauma. These variables included age, gender, race (Black, White, Hispanic, other), insurance status (uninsured, commercial insurance, government insurance, other) and anatomical and physiological severity using the ISS and Revised Trauma Score (RTS) [11], respectively. Race and insurance status were included as variables given recent data suggesting their independent effect on trauma outcomes [12, 13]. As our outcome measures included functional parameters, we further adjusted patients for the presence of severe head injury and/or severe extremity injury using the Abbreviated Injury Scale [14]; an Abbreviated Injury Scale ≥ 3 in the head or extremity or part was deemed severe, respectively.

Stata version 10 (Stata Corp., College Station, TX) was used for all statistical calculations. Student's *t*-test was used to compare continuous variables, and χ^2 to compare categorical variables for univariate analysis. A multiple logistic regression was done to compare differences between the reference group (motor vehicle crash) and other MOI groups. Odds ratios were calculated after adjusting for patient demographics and injury severity described above. Statistical significance was defined as $P < 0.05$.

RESULTS

Of the 1,466,887 patients entered into the NTDB over the years studied, 515,464 (35%) patients met our inclusion criteria. Mean age was 39 y, 69% were male, 73% White, and 41% had commercial health insurance (Table 2).

Unintentional injury was identified as a characteristic in 99% of patients, and overall crude mortality was 5.96%. Injury severity characteristics by MOI group are described in Table 3. Mean ISS (19.4) and

mortality rate (10.84%) was highest for pedestrians struck by motor vehicle. Extremity injury was highest among pedestrians struck by motor vehicle (20%), and head injury highest for motor cycle crash victims (16%).

Functional deficit data were not reported by approximately 30% of hospitals in the NTDB, accounting for approximately 40% of patients in our sample. The total number of patients reported on by hospitals that did send the NTDB functional outcome data were 309,274, of which 269,614 (88%) had functional outcome data appropriate for analysis. Of these patients, 63% had at least 1 functional deficit at discharge from hospital and 52% of patients had impaired walking, 16% had impaired feeding, and 10% had impaired speech (Table 4).

On multivariate analysis, age, RTS, ISS, race, and insurance status were all found to be independent predictors of the main outcome measure as expected. Table 5 describes the independent influence of MOI on outcomes following blunt trauma compared with the reference group (motor vehicle crash). The adjusted odds of death, impaired walking, and speaking were highest for pedestrians struck by a motor vehicle, and impaired feeding highest for motor cyclists compared with patients involved in a motor vehicle crash. Bicyclists and those who fell on the same level had the lowest odds of death or impairments compared with the reference group.

TABLE 4
Functional Impairment for Each Domain by Mechanism of Injury

Functional domain	All patients (<i>n</i> = 269,614)	MVC (<i>n</i> = 126,629)	Pedestrian struck by MV (<i>n</i> = 15,948)	Motorcycle crashes (<i>n</i> = 19,184)	Bicycle crash (<i>n</i> = 7,096)	Falls at same level (<i>n</i> = 68,878)	Falls from any height (<i>n</i> = 31,879)
Any impairment, %	63	56	70	61	42	74	60
Walking, %	52	53	68	56	38	70	56
Speaking, %	10	9	11	8	7	11	9
Feeding, %	16	14	16	15	10	17	15

MVC = motor vehicle crash; Pedestrian struck by MV = pedestrian struck by motor vehicle.

TABLE 5

Adjusted Odds of Death/Impairment by Mechanism of Injury versus Motor Vehicle Crashes $n = 269,614$

Death/functional impairment	MVC ($n = 126,629$)	Pedestrian struck by MV ($n = 15,948$)	Motorcycle crashes ($n = 19,184$)	Bicycle crash ($n = 7,096$)	Falls at same level ($n = 68,878$)	Falls from any height ($n = 31,879$)
Death	1	1.49*	1.03	0.76*	0.60*	0.69*
95% C.I.		1.38–1.57	0.96–1.19	0.65–0.88	0.54–0.67	0.63–0.74
Walking	1	1.68*	1.20*	0.58*	0.97	1.14*
95% C.I.		1.63–1.83	1.16–1.27	0.55–0.65	0.95–1.03	1.10–1.18
Speech	1	1.19*	1.07	0.86	0.97	1.18*
95% C.I.		1.10–1.31	0.99–1.16	0.73–1.04	0.93–1.06	1.12–1.26
Feeding	1	1.09*	1.18*	0.75	0.99	1.03
95% C.I.		1.03–1.18	1.12–1.25	0.69–0.85	0.95–1.04	0.97–1.07
Any deficit	1	1.49*	1.28	0.65*	1.23*	1.01
95% C.I.		1.61–1.77	1.23–1.33	0.61–0.69	1.17–1.29	0.91–1.10

* 95% confidence interval (95% C.I.) does not cross 1.

DISCUSSION

In this study, mechanism of injury is an independent predictor of mortality and functional impairment at the time of hospital discharge. After adjusting for injury severity and other confounders and using MVC victims as a reference group, blunt trauma patients of otherwise equivalent injury severity had significantly different outcomes based on the mechanism of their injury. Specifically, pedestrians struck by a motor vehicle had increased odds of death or impaired walking and speaking, and motorcyclists had higher odds of impaired feeding. These data are compelling in that very few analyses include MOI as a variable in outcome analysis.

Force and energy transfer is a major factor affecting patient outcomes following blunt trauma. When comparing motorcycle and bicycle crash victims, motorcyclists had higher odds of death or impairment in all 3 categories of daily living. Individuals who fell from a height also had worse outcomes than those who suffered same level falls, although the odds differences were not as dramatic as the motorcyclist and bicyclist comparison. While trauma patients in these comparison categories may suffer similar injuries, these outcome differences are likely modulated by the MOI through velocity and subsequent energy transfer. Different MOI categories also appear to lend themselves to certain death and disability patterns. Despite controlling for injury severity/demographics, injury mechanisms such as pedestrian struck by motor vehicle were associated with increased odds of death and impairments, whereas falls from a height were associated with decreased odds of death but increased odds of functional impairments compared with motor vehicle crashes.

We used multiple logistic regression to control for anatomical injury severity, physiological injury severity, head and extremity injury severity, age, gender,

race, and insurance status to remove known confounders of outcomes following trauma. These variables were included in the analytic model because previous research has shown their independent effect on outcomes. These data demonstrated results in the direction expected based on previous studies involving these variables. For example, age was associated with worse outcome, and injury severity was expectedly associated with worse outcomes, lending construct validity to our results [15, 16]. Further, we found that minority and uninsured patients were more likely to be pedestrians struck by motor vehicle, which again would be expected due to the increased population of minorities in cities where this mechanism is a known problem [17].

Information concerning MOI is useful at the scene of injury, and decisions at this point in time may predict later outcomes. For example, MOI can augment field triage decisions and can assist on-scene emergency personnel to consider potential injuries such as a thoracic aortic tear or cervical spine injury in their initial assessments [1, 18]. In a retrospective analysis of all admissions to a level I trauma center, MOI was a significant predictor for immediate operating room or intensive care needs [19]. In a separate study of patients >65 y of age, MOI was linked to injuries sustained, and suggested as a diagnostic tool when assessing a patient's condition following trauma [20]. With the evidence taken in total, we believe the current injury severity assessment models would be greatly enhanced if MOI were added. In addition, we suggest that comparative analyses or analyses used to benchmark outcomes among trauma centers should risk-adjust for MOI.

Study limitations include the standard issue of available clinical data when using a trauma registry. We were not able to account for previous or comorbid conditions or complications after admission that may affect outcomes. Of the large total number of patients

captured in the NTDB and meeting inclusion criteria, just over half were suitable for analysis of functional outcomes. Systematic nonreporting of data from a large number of hospitals participating in the NTDB has been described [21]. There were a significant number of hospitals that did not report functional outcome data, which is consistent with this characteristic; however, for those patients with complete data, the analysis should be considered sound. Finally, there is no consistent data on the potential long-term nature of the identified functional impairments.

We believe MOI is an underappreciated determinant of trauma outcomes, and mechanism of injury is an independent predictor of mortality and functional impairment among blunt trauma patients at hospital discharge. The fact that otherwise equivalently injured trauma patients had significant outcome differences based on the mechanism by which they were injured suggests that MOI should be routinely adjusted for in trauma outcomes research.

ACKNOWLEDGMENTS

The authors thank Christine G. Holzmueller, B.A., for her assistance in preparation and editing of this manuscript.

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