What Mechanism Justifies Abdominal Evaluation in Motor Vehicle Crashes?

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Background: Significant resources are spent on assessment of the abdomen in motor vehicle crash (MVC) occupants based solely upon crash mechanism. Most have no clinically significant injuries. We sought to define crash and occupant characteristics that would be associated with a low probability of clinically significant abdominal injury.

Methods: Drivers in MVCs were analyzed from the National Automotive Sampling System from 1993 to 2001. The probability of abdominal injury with an Abbreviated Injury Score > 1 was measured over a range of crash velocities controlling for other covariates using multivariate logistic regression. A receiver operating curve was used to assess the model.

Results: Age, restraint use, net change in velocity, ejection, rollover, vehicle type, other passenger mortality, and other injuries were included in the model yielding an area under the receiver operating curve of 0.948. The probability of abdominal injury increased significantly at velocities > 20 km/h and reached 5.0% at approximately 30 km/h. Age > 75 years old or the presence of head, leg, or chest injuries significantly increased the risk of abdominal injury, even at low velocities. Absence of injury to the head, spine, legs, or chest indicated that the abdomen was unlikely to be injured regardless of crash velocity.

Conclusion: Absence of injury to the head, chest, spine, and legs indicates an extremely low probability of abdominal injury, even at high velocities. Abdominal evaluation in this group of patients for reason of mechanism alone is therefore unnecessary.

Key Words: Abdominal injury, Motor vehicle crash, Mechanism, Elderly, Velocity.

In order for trauma systems to effectively reduce mortality, patients with potentially life-threatening injuries must be transported to the closest, most appropriate facility. In many systems, the guidelines recommended by the American College of Surgeons Committee on Trauma, which include physiologic, anatomic, and mechanistic criteria, are used for transport to a trauma center. Because life-threatening injuries may not be immediately obvious to prehospital personnel, an overtriage rate of between 30 and 50% is required to minimize undertriage. This overtriage rate comes primarily from patients transported for mechanistic criteria because most patients who truly have a serious injury suffer from either physiologic or anatomic derangements. As a result of this triage scheme, the trauma center is thus burdened with evaluating many patients who are minimally injured, if at all.

Abdominal evaluation of patients with blunt trauma is a large contributor to this burden. Intraabdominal injury is common after blunt injury, and physical examination alone is unreliable in determining either its presence or severity.

Serial abdominal examination, ultrasound, diagnostic peritoneal lavage, and abdominal computed tomography scan are all reliable methods to diagnose injury in the injured patients, although all increase resource consumption in the form of consumable resources and personnel time. Most of these evaluations will not demonstrate injury. To evaluate the potential of reducing the evaluation burden resulting from overtriage, we asked whether there were variables, both crash and patient related, available to clinicians in the emergency department that could predict the lack of intraabdominal injury with high enough accuracy to eliminate the need for further evaluation.

Methods

The National Automotive Sampling System (NASS) Crashworthiness Data System investigates approximately 5,000 crashes annually involving light passenger vehicles (passenger cars, vans, utility vehicles, and pickup trucks) in the United States. The Crashworthiness Data System is comprised of police-reported tow-away crashes and contains crash and occupant injury data. Police reported crashes are sampled according to a complex algorithm to produce nationally representative crash data. The sampling system was established in three stages: (1) the United States was divided into 1,195 primary sampling units (PSU), and 24 of these were selected based on probability proportional to population, (2) police agencies within each PSU were selected based on the number and type of crashes they process, and (3) crashes were selected from each police department with the...
The probability of selection influenced by the type of crash, severity of injury, and vehicle model year. This complex sampling algorithm results in each crash being assigned a weight proportional to its representation of national crash data. The weights result from the stages of selection, reflecting that crash’s probability of selection, using both a PSU and national inflation factor. The PSU inflation factor is the weight proportional to its representation of national crash sampling scheme, all analyses use values weighted according to this scheme to provide representative results. Statistical analyses were performed using Stata Software (version 7.0; StataCorp, College Station, Tex). In the present study, drivers in crashes within the NASS database from 1993 to 2001 were assessed. Because the selection of cases in the database uses a multistage, weighted sampling scheme, all analyses use values weighted according to this scheme to provide representative results. Statistical analyses were performed using Stata Software (version 7.0; StataCorp, College Station, Tex). Minimal to no abdominal injury was defined as an abdominal AIS ≤ 1 and was dichotomized as such (AIS ≤ 1 versus > 1). Injuries to other body regions were similarly dichotomized (AIS ≤ 1 versus > 1). Univariate logistic regression analyses were then performed to assess the association between abdominal injury and crash, vehicle, and occupant related variables. Those variables found to be associated with abdominal injury were incorporated into a multivariate logistic regression analysis. A backwards stepwise approach was used with a significance of p < 0.1 used as a cutoff to include variables in the model. Receiver operating curves were then used to assess the sensitivity and specificity of the final model. Based upon this model, the probability of abdominal injury was determined as it relates to crash velocity. The effect of age upon the probability of abdominal injury as it relates to crash velocity was then assessed through several age stratifications. The effects of restraint use, another occupant death in the crash, ejection, and other injuries on the probability of abdominal injury as it relates to the crash velocity of the crash were also assessed. Data for velocity were missing ejection were assessed through several age stratifications. The effects of restraint use, another occupant death in the crash, ejection, and other injuries on the probability of abdominal injury as it relates to the crash velocity of the crash were also assessed. Data for velocity were missing approximately half the cases; however, the proportion with missing velocity data having moderate to significant abdominal injury was similar to the proportion of cases with missing velocity data having minimal to no abdominal injury (50.6 versus 49.8%, respectively; Pearson χ² = 12.10; p = 0.46).

**RESULTS**

There were a total of 56,466 drivers within the weighted NASS dataset. Using the weighted sampling strategy to extrapolate to a United States population, this is equivalent to a
population of 28,904,475 drivers. A total of 2,283 (0.6%) drivers sustained moderate to severe abdominal injury (AIS/H11022). The remainder sustained either minimal injury (abdominal AIS/H11005) or no abdominal injury. Number and distribution of abdominal and extraabdominal injuries, according to severity, are listed in Table 1. Airbags deployed in 15.6% of crashes, and drivers were restrained in 72.8% of cases. The primary direction of impact for the majority of crashes was frontal (60.2%).

In univariate analysis, variables found to be associated (either increased or decreased risk) with abdominal trauma included age, restraint use, rollover, velocity, body type, ejection, other injuries, and death of another passenger (Table 2). The area under the receiver operating curve for a model including all these predictors was 0.948. All factors identified in the univariate analysis were included after backwards stepwise elimination. The multivariate logistic regression equation is log odds of abdominal AIS/H11022 > 1 = -4.96 - 0.012 (age) - 0.11 (seat belt use) - 0.43 (rollover) + 0.02 (delta velocity) - 0.29 (medium size vehicle) - 0.32 (large vehicle) + 0.61 (ejection) + 0.63 (other passenger death) + 1.44 (leg injury) + 2.57 (chest injury) + 0.60 (spine injury) + 0.74 (head injury).

The effect of age on the probability of abdominal injury did not become significant until age > 75 years old, at which point the probability of injury was 5.5% at a delta velocity of only 10 km/h. For those older than 75 years, the probability of injury did not begin to increase until a delta velocity of more than 20 km/h was reached (Fig. 1). The presence of chest, leg, or head injuries is associated with an increased probability of abdominal injury, even at low velocities, with chest injuries having the greatest effect. The presence of a spine injury increased the probability of abdominal injury at moderate to higher velocities but did not increase the probability of an abdominal injury at lower velocities (Fig. 2). There was no significant difference in the probability of injury as velocity increased when stratified by restraint use (Fig. 3), ejection, or whether another passenger died in the crash. At low velocities, in the absence of any injury to the head, chest, spine, or legs, the probability of abdominal injury was extremely low. The probability did not exceed 1.0% until a delta velocity of 50 km/h was reached. Additionally, the presence of either spine, chest, thorax, or head injuries was associated with a probability of abdominal injury of ≥4.5%, even at low velocities (Fig. 4). Age was also found to be an effect modifier of the relationship between velocity and abdominal injury.

**DISCUSSION**

As predicted by the laws of physics and confirmed by numerous authors, the probability of clinically important abdominal injury is significantly associated with change in velocity.12–15 In younger patients, the lower threshold for the sigmoidal curve is 20 km/h, with an overall incidence of abdominal injury of 5% at a velocity change of 30 km/h.
Disproportionate mechanistic criteria; patients sensitive criterion for the presence of injury, even without free of abdominal injury. The variability in negative injury. The lack of abnormalities is variably reported to has been used by others to predict absence of abdominal injury. One strategy is the two-tiered trauma team response based on triage criteria, with a more senior team and a more rapid response reserved for patients meeting physiologic (and some anatomic) criteria. A more junior team responds to patients meeting mechanistic (and some anatomic) criteria. Lansink et al., in a two-institution study, evaluated the ability of mechanistic criteria to predict the need for admission and serial examination when no other injury was found. No patient admitted for observation be-

From a resource use standpoint, the question is not whether velocity is predictive of abdominal injury, but what can predict the absence of abdominal injury when there is a significant change in velocity? In our model, other crash variables, including ejection, restraint use, or death of another passenger did not add significant predictive ability despite association shown in univariate analyses. This is likely because of the high correlation between velocity and these other mechanistic criteria.

The combination of chest and pelvic roentgenograms with physical examination, vital signs, and laboratory data has been used by others to predict absence of abdominal injury. The lack of abnormalities is variably reported to predict that anywhere from 12 to 100% of patients will be free of abdominal injury. The variability in negative predictive value is likely explained by the different patient populations studied. Our findings would support that chest and pelvic roentgenograms, as well as a careful physical examination with special attention to long bones and the spine, may be used as adjuncts not only to determine the presence of injury in extraabdominal regions, but also to determine whether evaluation for abdominal injury should be performed. If an extraabdominal injury is discovered during primary and secondary survey, the likelihood of intraabdominal injury is reasonably high. If no extraabdominal injury is found and there is no clinical need to evaluate the abdomen, the likelihood of intraabdominal injury is low.

The association of age with a higher mortality from moderate to severe injury, as compared with younger patients, is the reason for its inclusion as a comorbid condition triage criteria. These data suggest that age is a sufficiently sensitive criterion for the presence of injury, even without mechanistic criteria; patients ≥75 years old had a significant probability of intraabdominal injury, regardless of change in velocity. This higher propensity for abdominal injury is also seen in the elderly pedestrian, and may be due to decreased compliance of the elderly body wall. Disproportionate in-

Fig. 4. Probability of sustaining abdominal injury at increasing crash velocity by the presence of any extraabdominal injury.

jury severity with respect to mechanism is also seen for extraabdominal injuries in the elderly after falls. There may also be factors varying with age that were more directly responsible for the abdominal injury that were not examined in this analysis.

This analysis has several weaknesses that are common to models built on information gained from retrospective sources. To make the model as realistic and as applicable as possible, we included only that crash information we thought would be easily available for the prehospital personnel to obtain with reasonable accuracy. It is well known, however, that the estimated crash velocity based upon occupant history or bystander recall is often inaccurate. Therefore, accurate prehospital assessment of the crash velocity must be based upon degree of vehicle deformation, which may not be well appreciated by prehospital personnel. Importantly, this study was unable to assess the impact of clinical and physiologic findings on the probability of abdominal injury, because clinical and physiologic variables are not recorded in NASS. Initial hemodynamic parameters and clinical information, such as abdominal pain, tenderness, and the presence of a seat belt sign, all related to abdominal injury, are not available. The level of injury detail is also limited. Clearly, this information is available to the initial treating physician and would influence the decision whether or not to perform further evaluation for intraabdominal injury. In addition, there were relatively few drivers with serious abdominal injury, although because of the large numbers in the weighted dataset, this is not a significant statistical limitation.

Within a trauma system, overtage is required to reduce preventable mortality and missed injuries. However, it results in a significant number of minimally injured patients that must be evaluated at a Level I or II trauma center. Strategies to reduce the burden of intensive evaluation for these patients have been used by others. One strategy is the two-tiered trauma team response based on triage criteria, with a more senior team and a more rapid response reserved for patients meeting physiologic (and some anatomic) criteria. A more junior team responds to patients meeting mechanistic (and some anatomic) criteria. Lansink et al., in a two-institution study, evaluated the ability of mechanistic criteria to predict the need for admission and serial examination when no other injury was found. No patient admitted for observation because of the large numbers in the weighted dataset, this is not a significant statistical limitation.

Our model suggests that American College of Surgeons Committee on Trauma triage criteria, specifically mechanism-related criteria, do not mandate abdominal evaluation once a patient is transported to a trauma center. These criteria, with the exception of crash velocity, are not independently associated with the presence of abdominal injury. Although a complex regression algorithm is not likely to be helpful to a clinician treating a trauma patient, the results of this analysis should be. After a carefully performed primary and secondary survey, if no extraabdominal injuries are found and there are
no clinical or physiologic reasons to suspect intraabdominal injury, abdominal evaluation solely for a perceived high-risk mechanism is unnecessary. One notable exception to this general rule exists. The elderly have a much higher likelihood of intraabdominal injury, even at low velocity, and therefore should undergo evaluation to exclude injury, even in the absence of extraabdominal injuries.

REFERENCES