Fatality Risk and the Presence of Rib Fractures

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ABSTRACT – Rib fractures may be dismissed as clinically insignificant, or of secondary importance in a patient presenting with other serious injuries, especially if the patient is young. This study assesses the effect of concomitant rib injuries on fatality risk following a car crash, and compares the effect as a function of patient age. The National Trauma Databank was sampled to identify 181,331 adults that were in motor vehicle crashes and had complete data available. Characteristics among several populations were compared, including the association between rib fractures and fatality risk in two age groups (18 to 45 years old and over 64 years old). Descriptive statistics were compiled to contrast the injury patterns and outcomes. Propensity scores were then generated using logistic regression, where the "treatment group" was those patients with rib fractures of at least an abbreviated injury scale (AIS) 3. Covariates for generating the propensity score included gender and the presence or absence of AIS 3, 4 or greater injuries to the head, abdomen or pelvis. Matching was performed using calipers on the propensity scores for all patients within the two age groups. Odds ratios for the outcome death were calculated for the matched datasets and compared between the two age groups. The probability that an adult with automotive blunt trauma had a rib injury as the maximum AIS (MAIS) increased significantly ($p<0.001$) with age. Furthermore, the probability of the patient having an MAIS defined by rib fractures increased significantly with age for adults who died with a thoracic MAIS: from 30.4% at age 21 to 51.3% at age 65. Rib fractures defined the MAIS for 55.9% of all patients over age 60 who died with a thoracic MAIS. In other words, over 55% of patients over 60 who died of a chest injury had no injury worse than rib injuries. The odds ratio for death for younger patients (aged 18-45) was 1.4 (95% CI 1.3-1.6) if rib fractures of at least AIS 3 or greater were present. For older patients (over 64 years) the odds ratio was 2.5 (95% CI 2.3-2.8). In other words, regardless of the presence or absence of concomitant trauma, crash-injured patients with rib fractures of at least AIS 3 have a significantly increased risk of in-hospital mortality, and of two patients having similar non-rib trauma, one with AIS 3+ rib fractures has a substantially higher expected risk of death than one without. This effect is more dramatic for older patients.

INTRODUCTION

Rib fractures are the most common skeletal thoracic injury sustained by restrained occupants in frontal crashes (Pattimore 1992). Arajavi et al. (1989) identified rib fractures in 93.5% of severely or fatally injured seatbelt wearers. While rib fractures are a frequent result of collisions, they are generally considered to be life threatening only when they occur in the elderly (e.g., Bulger et al. 2000) or persons with pre-existing pulmonary disease, or if they are of sufficient extent and distribution to allow paradoxical respiration (flail chest). The clinical manifestations of rib fractures include pain and restriction of effective ventilation function, either by limitation from pain or by mechanical limitation. Pain can lead to decreased ventilation, decreased vital capacity, diminished ability to clear secretions, and retention of carbon dioxide (Cogbill and Landercasper 1996). As more ribs are fractured, there is a progression of pathophysiological findings, including ventilation-perfusion abnormalities, increased respiratory work, hypoxemia, and decreased functional residual capacity. Multiple rib fractures can be associated with an increased likelihood of intrathoracic and abdominal injuries simply because of the magnitude of trauma required to fracture several ribs. Bassett (1968) demonstrated that the incidence of intrathoracic injuries rises approximately 10% with each rib fractured. Localized thoracic loading, such as seatbelt impingement, can generate displaced fractures that result in rib segment penetration and damage to the underlying soft tissue. Displaced fractures of ribs in close proximity to the lungs can puncture the underlying pleura and parenchyma, causing hemothorax or pneumothorax.

An aging person becomes increasingly susceptible to thoracic injury, primarily rib fractures, from seatbelt loading in a crash. The ease with which ribs fracture and the ability to tolerate rib fractures both change substantially as a person ages. In the young, the material and geometric characteristics of the ribs result in a structure that is relatively difficult to damage. As a person ages, bone demineralizes and becomes more porous, resulting in a decrease in material strength (e.g., Lindahl and Lindgren 1967, Cowin 2001). In addition, the rib cage tends to get narrower and deeper, while the layer of cortical bone decreases in thickness (Kent et al. 2005b, Stein and Granik 1976). These changes tend to decrease rib fracture tolerance (Kent and Patrie 2004, Laituri et al. 2005) and are compounded by several characteristics of older people that render them unable to tolerate rib fractures. First, the young have more efficient blood-oxygen exchange and higher pain tolerance, which increase their ability to tolerate rib fractures and damage to the lung parenchyma. Second, aging is associated with stiffening of the chest wall and decreased thoracic muscle, which lead to decreased effective cough and ability to clear secretions. Furthermore, as a person ages the alveoli coalesce, resulting in a reduction of small airways in the bronchial tree, and cardiac output decreases, which leads to compromised blood oxygenation. Finally, aging is associated with atrophy of the epithelium lining the bronchi, which predisposes an older person to chronic colonization of the upper airway with bacteria and facilitates pneumonia.

Both of these aspects of aging (increased risk of rib fractures occurring and decreased ability to tolerate them when they occur) are reflected in the field experience of older occupants in vehicles. Morris et al. (2002, 2003) identified the disproportionate importance of chest injuries for older drivers, particularly those caused by restraint loading. Kent et al. (2005a) corroborated these findings and showed that 47% of drivers over 64 years of age who died in a frontal crash sustained a fatal chest injury. Furthermore, many of these fatal thoracic injuries in the elderly are not particularly severe. A recent study conducted using data from the Crash Injury Research and Engineering Network (CIREN) found that rib fractures were the most serious injury sustained by 40% of patients over 60 who died of chest injuries from automobile collisions (Kent et al. 2005b).

The purpose of the current work is two-fold. The first goal is to assess, using a larger dataset, the 40% proportion discussed above, which was based on a limited sample of CIREN data. The second goal is to assess and isolate the role of rib fractures as a comorbidity factor in crash-involved trauma patients. Several studies, as described in limited detail above, have identified associations between the presence of rib fractures, the degree of other trauma, and the patient's final outcome. It is generally found in such studies that the number of rib fractures is monotonically associated with more severe forms of trauma, and therefore an increased risk of death. This is presumably due to the presence and number of rib fractures being highly correlated with the severity of impact(s) sustained by the patient. This study seeks to isolate the effect of concomitant rib fractures through the use of propensity scoring to identify patient groups that are similar in injury composition except for the presence of rib fractures. In this way, patients presumably exposed to more comparable impact severity levels can be compared to study the influence of rib fractures on their outcomes.

METHODS

Isolating the role of rib fractures requires a large amount of patient injury data. Databases traditionally used to study the injury patterns of vehicle occupants in crashes [National Automotive Sampling System-Crashworthiness Data System (NASS-CDS), CIREN, the Cooperative Crash Injury Study (CCIS), etc.] do not contain sufficient data to isolate sub-populations using propensity scores based on injury patterns, especially since death is an outcome of interest in this work. The NASS-CDS, for example, includes only approximately 500 deaths per year. In contrast, the U.S. National Trauma Databank (NTDB), compiled and maintained by the American College of Surgeons (ACS), contains injury information for approximately 1.5 million trauma cases from over 600 trauma centers in the United States, making it the largest aggregation of trauma registry data ever assembled. The NTDB was used in this study after receiving the required written permission from the ACS and approval from the IRB at the University of Virginia.

Development of Database for Analysis

The NTDB includes Abbreviated Injury Scale (AIS) codes (AAAM 1998), demographics, final outcome, and broad injury mechanism information via CDC-defined e-codes (e.g., motor vehicle crash) for trauma patients treated as an outpatient or inpatient by participating trauma centers (ACS 2006). The NTDB does, however, have some important limitations for studying car occupant injury patterns. In contrast to NASS-CDS and other crash-focused databases, the NTDB does not include information about the crash (only that the patient was injured in a motor vehicle crash). Furthermore, rural and urban trauma centers of all levels voluntarily participate in the NTDB program, so patient outcomes are confounded to the extent that the level of care differs among hospitals, and there are other sources of bias in the data (see ACS 2006). NTDB is not a census of U.S. trauma patients, and it is not intended to be nationally representative. Nonetheless, the large size and scope of the NTDB make it a valuable tool for addressing the research aims of this study, and results generated from the NTDB do reflect a large proportion (approximately 75%) of the U.S. trauma patient population.

The NTDB data are contained in 14 related files (AISCode, Comorbid, Complic, Demo, Diagnos, ED, Facility, Intub, Mechanism of Injury, Outcome, PreHProc, Precedur, Scene, and Safety) (ACS 2006), each containing several linkable data fields. The files were sampled using the Motor vehicle traffic E-codes E810-E819 (.0-.9), to identify 257,155 occupants in a motor vehicle crash. Excluding penetrating and burn trauma and including only adults age >17 years reduced the dataset to 212,872 patients. A data quality check revealed several inconsistent codes (e.g., "dead" coded in one field and "alive" coded in another for the same patient), which were excluded from the dataset. Finally, patients with MAIS = 0, ISS = 0, or injuries coded as AIS = 9 were excluded. This set of inclusions and exclusions yielded a final population of 181,331 patients who sustained 592,003 injuries. This population was defined as "injured" and their demographic, injury, and outcome data were compiled into a single data file for further analysis. All of the sub-populations discussed in this paper are subsets of that "injured" population.

Descriptive Analysis and Injury Probability Models

The subpopulation "Injured who Died" was defined as patients who had DISSTATUS = "Dead" coded in the Outcome file. There were 9,002 such patients. Patients having at least one MAIS code with a 4 as the first digit (i.e., the "body region" digit) were defined as "Injured with a thoracic MAIS" (n=68,697) and patients having at least one MAIS code in the range 450202.1 through 450899.9 were defined as "Injured with a rib MAIS" (n=39,352). In cases with AIS coding errors (e.g., a non-existent AIS code in the "AISCODE" column), the data columns "AISDESCR" and "BODYREGION" were used to identify rib or thoracic MAIS cases. Obviously, the latter subpopulation (rib MAIS) is a subset of the former (thoracic MAIS). Patients over age 89 were grouped for analysis.

The probability of death was determined both empirically as a simple ratio in each population and using binary univariate and multivariate regression models. Three outcome variables, *Died*, *Thorax MAIS* and *Rib MAIS*, were defined. Patients in the "Injured who Died" category were assigned the variable value *Died* = 1, while *Died* = 0 for all other patients. For those patients in the "Injured with a thoracic MAIS" population, the variable *Thorax MAIS* = 1, else *Thoracic MAIS* = 0. Similarly, for patients in the "Injured with a rib MAIS", *Rib MAIS* = 1, else *Rib MAIS* = 0. The probabilities, *P(I)*, of those three variables having the value one were modeled as exponential functions of several predictors, x_i:

$$P(I) = \frac{1}{1+e^{-q}} \qquad [1]$$

where

$$q = \alpha + \sum_i \beta_i x_i \qquad [3]$$

is a linear function with intercept α and coefficients β_i associated with each predictor. Univariate (i = 1) models used the patients age (years) as a predictor of those outcomes. Multivariate (i > 1) models included the additional covariates gender (binary, 1 = male) and the year of discharge (variable "Year"). The number of trauma patients seen by the trauma center treating the patient, in the year that the patient was treated (variable "N.T.P."), was also considered as a covariate. Consideration of this number was attempted as a gross proxy for variation in outcomes based upon a center's patient volume and thus level of experience.

Grouping by Propensity Scores and Assessment of Fatality Risk Associated with Rib Fractures

To isolate the role of rib fracture as a comorbidity factor, the population of injured occupants was divided into two groups based on age at admission:

18 years ≤ age ≤ 45 years (younger), and
age > 64 years (older).

Holcomb et al. (2003) noted an increase in mortality for all those over age 45 years with rib fractures and no other AIS 3 or greater head or abdomen injury. Using this data, there appears to be two natural inflection points on the mortality rate curve: the rate of increase of the risk of death increases at age 45, and then increases again at age 65. The two age groups studied here were chosen based upon the inflection points of the curves in Holcomb's work.

With this age breakdown, 116,353 younger patients and 24,053 older patients were identified. Propensity scoring techniques were used to identify pairs of occupants, within those age groups, who were equally likely to have AIS 3 or greater rib fractures based upon their list of other injuries and demographics (covariates of Table 1). Matched pairs of patients that are similar in a variety of ways, except for the presence or absence of rib fractures, can thus be identified and the risk of death compared. The impact of rib fractures on mortality for those with more than just isolated rib fractures can then be studied. A propensity score was generated for all patients using logistic regressions of the form shown in Equations [1] and [2] where patients with an AIS 3+ rib fracture injury were considered the "treatment" group. Covariates for generating the propensity score included gender, and the presence or absence of AIS 3, 4 and greater injuries to the head, abdomen or pelvis (Table 1). Information about the crash exposure was not included since this information is not in the NTDB. Age was not included as a covariate since the patients were grouped by age for the analysis. The outcome modeled for the propensity scoring was the presence of AIS 3 or greater rib fractures. The probability of that outcome was determined from the model for each patient and defined as the propensity score for that patient. Matching of patients with and without AIS 3+ rib fractures was performed using calipers on the propensity scores for all patients within the two age groups. The caliper width was defined as 20% of the average variance of the propensity between the rib injured and uninjured patients within the same age group. Odds ratios for the outcome death were calculated for the matched datasets and compared between the two age groups.

Table 1. Covariates used for propensity scoring.

Gender	AIS 4 abdomen injury
AIS 3 head injury	AIS >4 abdomen injury
AIS 4 head injury	AIS 3 pelvis injury
AIS >4 head injury	AIS 4 pelvis injury
AIS 3 abdomen injury	AIS >4 pelvis injury

RESULTS

Descriptive Analysis and Injury Probability Models

The mean age differed among the patient populations considered (Table 2). The population of all injured occupants had a mean age of 40.3 years, while those with a thoracic MAIS had mean age 43.9 years and those with rib MAIS had mean age 47.7 years. The gender distribution among these populations was similar (58.2% - 59.0% male). Of all patients with a thoracic MAIS, 57.3% had a rib MAIS. A clear age trend can be seen when patients who died with a thoracic MAIS are isolated: 76.5% of patients over age 60 who died with a thoracic MAIS had a rib fracture MAIS. In other words, over three quarters of people over age sixty who died with a thoracic injury as their most serious injury had no injury worse than rib fractures. This percentage was substantially lower (54.2%) for patients under age sixty.

These trends are reflected in the regression models of the three populations (Table 3 and Figure 1). For the population of all injured occupants, age was a significant predictor of the outcome Thorax MAIS and Rib MAIS. The probability of a thoracic MAIS injury increased from approximately 30% at age 18 to 50% at age 65 and nearly 60% at age 85. The probability of a Rib MAIS increased from approximately 11% at age 18 to 33% at age 65 and nearly 50% by age 85.

Table 2. Description of populations considered.

	Injured	Thoracic MAIS	Rib MAIS	Died	Age 60+ died with thoracic MAIS	Age <60 died with thoracic MAIS
N	181,331 (58.2% male)	68,697 (59.0% male)	39,352 (58.5% male)	9,002 (62.8% male)	2,374 (55.3% male)	4,005 (64.5% male)
Mean age	40.3	43.9	47.7	49.3	76.3	34.2
Median age	36	41	46	47.0	77	32
Died	9,002 (5.0%)	6,379 (9.3%)	3,988 (10.1%)	--	--	--
Rib fracture MAIS	39,352 (22.0%)	39.352 (57.3%)	--	3,988 (44.3%)	1,817 (76.5%)	2,171 (54.2%)

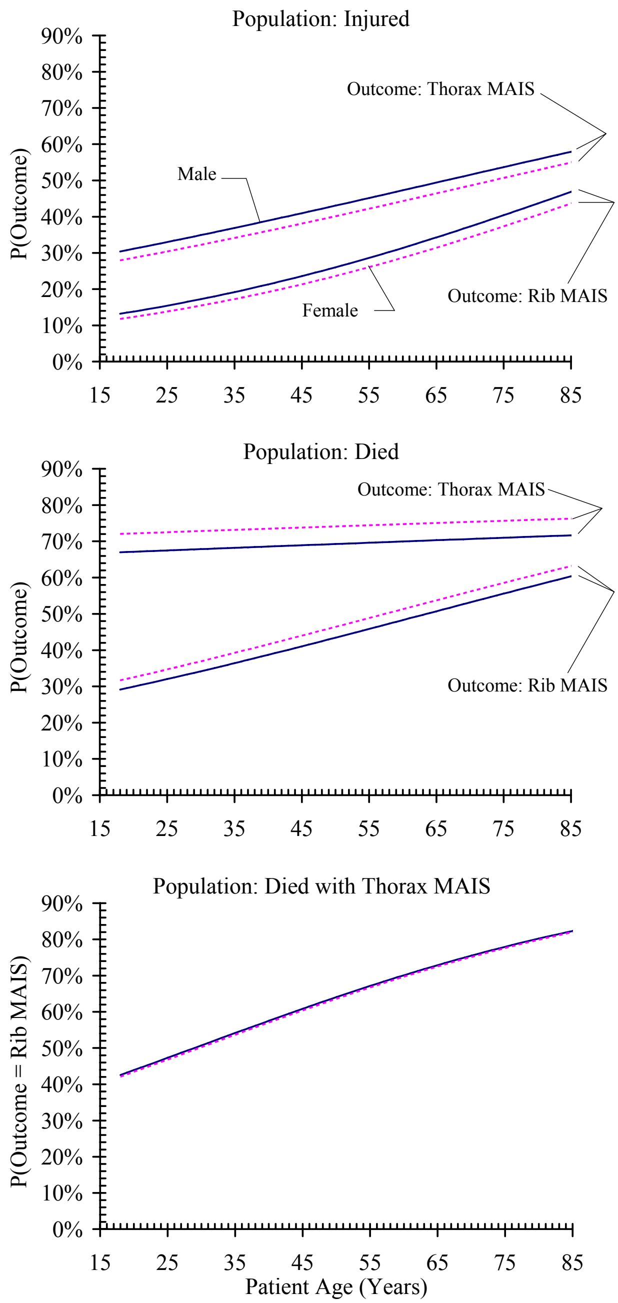

Figure 1. Results of regression models for three populations and two outcomes. All other covariates set to mean values in population dataset.

Interestingly, when only the patients who died were considered, the relationship between the probability of a thoracic MAIS and age, while significant, was small, with approximately 70% of all patients having a thoracic MAIS regardless of age. The probability of a Rib MAIS, however, was strongly influenced by age for the patients who died, increasing from approximately 30% at age 18, to just under 50% at age 65 and 60% at age 85. Finally, when the population of patients who died with a thoracic MAIS was modeled, it was found that over 80% of patients age 85 had an MAIS defined by rib fractures, while only 42% of 18-year-olds did. This is consistent with the raw ratios described above and supports the assertion that a substantial proportion of older crash-involved occupants who die of a chest injury have no injury worse than rib fractures.

Propensity Scores and Assessment of Fatality Risk Associated with Rib Fractures

Table 4 lists the regression coefficients identified for the young and old study groups, which were used to determine propensity scores for each patient. Table 5 defines the propensity score results for each of the study groups. The results of the outcomes among the matched pairs are listed in Table 6. The caliper definition used here resulted in only a few unmatched rib-injured patients (6 younger patients and 32 older). The average age of the patients in the matched groups is not significantly different despite the fact that patient age was not used as a covariate in the propensity score algorithm.

The propensity score matching algorithm generated 9,243 matched pairs for the 9,249 younger patients with rib fractures, and 4,366 matched pairs for the 4,398 older patients with rib fractures. The odds ratio for death for younger patients with rib fractures AIS 3 or greater was 1.4 (95% confidence interval 1.3-1.6) compared to those without rib fractures AIS 3 or greater. The odds ratio for death for the older occupants (over 64 years old) with rib fractures was 2.5 (95% CI 2.3-2.8) compared to those without AIS 3 or greater rib fractures. Thus, regardless of the presence or absence of concomitant trauma, motor vehicle occupants with rib fractures of at least AIS 3 have an increased risk of in-hospital mortality. This impact is more dramatic for older occupants.

DISCUSSION

In 2006, 42,642 deaths occurred in motor vehicle crashes (MVCs) in the US (www.nhtsa.dot.gov). Unintentional injuries were the fifth leading cause of death in 2004, with those from MVCs being the largest subset of that group. Understanding the age variation in mortality risks due to particular injuries or mechanisms of injury assumes added importance as the US population ages. Data and predictions from the US Census Bureau note that 12.4% of the US population was age 65 years or older in 2000. This percentage is expected to climb to 13% in 2010 and 19.7% by 2030. Kent et al. (2003) estimated that increased frailty from an aging population may become the most significant mechanism of changing injury outcomes from MVCs in the future.

Thoracic trauma frequently occurs in patients with severe injuries after a motor vehicle crash. The mortality risk from these thoracic injuries appears to be greater in older patients. Thoracic injuries, in particular to the bony structures, have been shown to be disproportionately important for older people involved in MVCs (e.g., Morris et al. 2002, 2003, Kent et al. 2005a). This study sought to further define the impact of thoracic skeletal trauma on older occupants in MVCs as a function of age. The descriptive analysis presented here identified some trends that support the earlier literature on this topic, but also some that warrant further investigation. As expected, the mean age varied for the different populations of patients studied. The population of all patients injured in MVCs had an average age of 40 years, but the mean age of the sub-population with a thoracic MAIS was 43 years, and with a rib fracture MAIS was 46 years. This appears to reflect the intrinsic reduction in thoracic (especially rib) injury tolerance that occurs with aging, which has been well documented (e.g., Stein and Granik 1976, Kent et al. 2005b). Consideration of other populations reflects the other critical aspect of rib fractures in older people: not only is it easier to generate rib fractures in an older person but the ability to tolerate rib fractures decreases with aging. Of the patients over age 59 who died with a thoracic MAIS, 76.5% had no injury worse than rib fractures. This percentage was only 54.2% when patients under age 60 were considered.

Regression models revealed that the probabilities of a thoracic MAIS and of a rib fracture MAIS both increased significantly with age in the population of all injured patients. The relationship with age did not hold, however, for thoracic MAIS in the population of patients who died. This finding may reflect the fact that the vast majority of patients who die after an MVC sustain multiple injuries to multiple body regions, and the thorax is frequently one of the body regions injured severely when a MVC patient dies. It may also reflect the fact that younger people who die are, on the whole, involved in more severe crashes than older people. The age association with rib fractures, however, remains even in the population of patients who die, suggesting that the younger patients who die sustain visceral thoracic trauma at a greater frequency than older patients who die. Future work should include a detailed breakdown of the thoracic injury distribution of these patient groups by age.

Table 3. Regression model results for several populations and outcomes (also see Figure 1).

Population	Outcome	$\gamma^{\#}$	Goodness of Fit^ χ^2	Goodness of Fit^ p	α^*	β_i^* Age (years)	β_i^* Gender (1=F)	β_i^* N.T.P.†	β_i^* Year‡
Injured	Thorax MAIS	0.19	45.1	<0.001	-34.21 (p<0.001)	0.01713 (p<0.001)	-0.12 (p<0.001)	$5.2(10^{-5})$ (p<0.001)	0.01646 (p<0.001)
Injured	Rib MAIS	0.30	466	<0.001	-25.62 (p=0.003)	0.02624 (p<0.001)	-0.13 (p<0.001)	$6.5(10^{-5})$ (p<0.001)	0.01155 (p<0.001)
Died	Thorax MAIS	0.09	12.4	0.135	-12.53 (p=0.721)	0.00329 (p=0.001)	0.24 (p<0.001)	$6.0(10^{-5})$ (p=0.005)	0.00652 (p=0.710)
Died	Rib MAIS	0.27	33.3	<0.001	64.68 (p=0.050)	0.01956 (p<0.001)	0.12 (p=0.008)	$-4.1(10^{-5})$ (p=0.041)	-0.03287 (p=0.046)
Died with Thorax MAIS	Rib MAIS	0.36	44.9	<0.001	87.86 (p=0.032)	0.02742 (p<0.001)	-0.02 (p=0.658)	$-11(10^{-5})$ (p<0.001)	-0.04415 (p=0.050)

#Goodman-Kruskal Gamma measure of association; ^Hosmer-Lemeshow test (8 DOF); *Model coefficients, see Equation [2]; †Number of trauma patients seen by that center in that year; ‡Year injury occurred

Table 4. Regression coefficients used to determine the propensity score for each patient.

	Younger (18-44 years)	Older (>64 years)
Goodman-Kruskal Gamma	0.390	0.252
Hosmer-Lemeshow test χ^2	2.98 (3 DOF, p=0.395)	35.99 (2 DOF, p<0.001)
α	4.376 (p<0.001)	5.802 (p<0.001)
Gender (1=female)	0.139 (p<0.001)	0.050 (p=0.143)
Head injury = AIS 3 (1= yes)	-0.441 (p<0.001)	-0.321 (p<0.001)
Head injury = AIS 4 (1= yes)	-0.431 (p<0.001)	-0.249 (p<0.001)
Head injury > AIS 4 (1= yes)	-0.677 (p<0.001)	-0.415 (p<0.001)
Abdomen injury = AIS 3 (1= yes)	-1.209 (p<0.001)	-1.005 (p<0.001)
Abdomen injury = AIS 4 (1= yes)	-1.295 (p<0.001)	-0.976 (p<0.001)
Abdomen injury > AIS 4 (1= yes)	-1.556 (p<0.001)	-1.095 (p<0.001)
Pelvis injury = AIS 3 (1= yes)	-0.783 (p<0.001)	-1.038 (p<0.001)
Pelvis injury = AIS 4 (1= yes)	-0.559 (p<0.001)	-1.172 (p<0.001)
Pelvis injury > AIS 4 (1= yes)	-0.309 (p=0.096)	-1.284 (p<0.001)

Table 5. Propensity score results.

	Younger (n=116,353)	Older (n=24,053)
Number with rib fracture	9,249	4,398
Number with no rib fracture	107,104	19,655
Number alive at hospital discharge	112,076	21,243
Did not survive until hospital discharge	4,277	2,810
Average propensity score for rib injured	3.847	5.477
Average propensity score for those without rib injury	4.232	5.680
Variance of the propensity score for the rib injured	0.606	0.329
Variance of the propensity score for those without rib injury	0.200	0.117
Caliper width	0.090	0.049
Number of matched pairs	9,243	4,366

Propensity score methods were chosen to study the impact of rib fractures in those patients with other injuries. The impact of a particular factor (rib fractures in this case) on an outcome (in-hospital mortality) in retrospective observational studies has historically been assessed using regression techniques. Propensity score methods have been advocated recently as a method of minimizing covariate bias in these observational studies. The propensity score is defined as "the conditional probability of being treated, given the individual's covariates" (D'Agostino 1998). In the current study, a patient's propensity score reflects the probability that the patient sustained severe rib fractures (the "treatment" in this case). While not suggesting that the covariates are causative of the severe rib fractures, the propensity score serves as a balancing score (Rosenbaum and Rubin 1983). Patients matched by propensity score were nearly equally likely to have a severe rib fracture, based upon the chosen covariates, yet one of the pair did not sustain the severe rib injury. By comparing the fatality outcomes of these pairs, an assessment of rib fractures on death risk can be made independently of concomitant trauma.

The accuracy of propensity score methods depends upon adequately identifying and defining the significant covariates. The injury severity score in this case was not an effective covariate because it is dependent upon the outcome being modeled. Additionally, there was not enough pre-existing medical information in the NTDB to determine the role of pre-existing conditions. Other limitations of the NTDB are, of course, reflected in the propensity scores and regression models generated in this study.

The data demonstrate that regardless of the level of concomitant trauma, motor vehicle occupants with rib fractures of at least AIS 3 have an increased risk of in-hospital mortality. This finding is consistent with age-related mortality risks defined by those studying patients with rib fractures and no other significant concomitant trauma (Holcomb 2003, Brasel 2006), or unmatched extra-thoracic trauma (Brasel 2006, Bulger 2000), but an important addition to the literature since the bias introduced by variability in concomitant trauma has been lessened through the propensity scoring. The increased mortality risk associated with rib fractures was found to have a significant age aspect. The odds of dying were 1.4 times greater for a younger patient with AIS 3+ rib fractures than for a patient of similar age and injuries but without AIS 3+ rib fractures. For older patients, this ratio was 2.5. For both age groups the odds ratios are significantly greater than 1.

Table 6. Comparison of patient groups after matching via propensity scores.

	Younger		Older	
	Rib fracture (n=9,243)	No rib fracture (n=9,243)	Rib fracture (n=4,366)	No rib fracture (n=4,366)
Average age	30.6 years	27.99 years	76.4 years	75.9 years
No. with rib injury MAIS	6,552	0	3508	0
No. with thoracic injury MAIS	7,566	1,249	3,866	568
Females	3,320	3,284	2,262	2,259
Discharged alive	8,241	8,506	3,231	3,835
Death prior to hospital discharge	1,002	737	1,135	531
Average ISS	26.9	16.3	24.1	13.0
No. with rib injury = AIS 3	6,281	0	2,724	0
No. with rib injury = AIS 4	2,567	0	1,381	0
No. with rib injury > AIS 4	441	0	288	0
No. with head injury = AIS 3	1,561	1,572	616	611
No. with head injury = AIS 4	933	888	426	433
No. with head injury > AIS 4	728	793	174	169
No. with chest injury = AIS 3	6,590	1,581	2,953	565
No. with chest injury = AIS 4	3,577	492	1,633	148
No. with chest injury > AIS 4	697	98	417	52
No. with abdomen injury = AIS 3	1,196	1,268	346	350
No. with abdomen injury = AIS 4	721	673	145	143
No. with abdomen injury > AIS 4	309	274	55	47
No. with pelvis injury = AIS 3	1,041	967	453	457
No. with pelvis injury = AIS 4	104	131	35	37
No. with pelvis injury > AIS 4	46	47	16	16
Average MAIS	3.8	3.0	3.7	2.7
No. with any rib injury	9243	0	4366	0
No. with any head injury	2,615	2,601	1039	1037
No. with any thoracic injury	9,243	2,054	4366	730
No. with any abdomen injury	2,064	2,014	513	501
No. with any pelvis injury	1,167	1,113	503	508

The current study also demonstrates that a significant proportion of in-hospital deaths after MVC involve patients with severe rib fractures.

CONCLUSION

The probability that an adult with automotive blunt trauma has a rib fracture MAIS increases significantly with age. Furthermore, the probability of the patient having an MAIS defined by rib fractures increases significantly with age for adults who die with a thoracic MAIS. In fact, rib fractures define the MAIS for over 55% of all patients over age 60 who die with a thoracic MAIS. In other words, most patients over 60 who die of a chest injury have no injury worse than rib fractures.

Furthermore, the presence of rib fractures is associated with a significant increase is fatality risk, regardless of concomitant trauma. The odds ratio for death for young occupants (aged 18-45) was found to be 1.4 (95% CI 1.3-1.6) if rib fractures of at least AIS 3 or greater were present. For older occupants (over 64 years) the odds ratio was 2.5 (95% CI 2.3-2.8). In other words, regardless of the presence or absence of concomitant trauma, motor vehicle occupants with rib fractures of at least AIS 3 have a significantly increased risk of in-hospital mortality, and of two patients having similar non-rib trauma, one with AIS 3+ rib fractures has a substantially higher expected risk of death than one without. This impact is more dramatic for older patients.

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