

THE RELATIONSHIP BETWEEN THORACIC ORGAN INJURIES AND ASSOCIATED RIB FRACTURES

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ABSTRACT

Thoracic trauma can involve serious injuries of both the rib cage and thoracic organs. The leading cause of thoracic trauma is motor vehicle crashes (MVCs). Rib fractures are often associated with injuries to the underlying organs. This paper investigates the situations in which lung, liver, and spleen injuries occur with associated rib fractures. Side impacts were found to have corresponding organ injuries and rib fractures more often than frontal crashes. Contingency tests were performed and the results revealed that a significant difference exists between organ injuries with rib fractures as opposed to organ injuries without rib fracture. The rate of injury for the spleen and liver were found to correlate with the struck side of the vehicle.

Keywords: Rib Fracture, Thoracic Organ, Injury Probability, NASS/CDS, Injury Relationships.

INTRODUCTION

Trauma is the third leading cause of death in the United States, and the leading fatality risk for those under forty years of age [1-3]. Thoracic trauma represents 10-15% of all trauma and leads to 25% of all deaths related to trauma. Blunt trauma of the chest is more common than penetrating trauma and the majority of blunt chest traumatic injuries are the result of motor vehicle crashes (MVCs) [1-6]. Rib fractures are often associated with blunt chest trauma (70%), and the severity and number of fractures can dictate the severity and survivability of a traumatic event [2]. Sirmali et al (2003) investigated 548 cases of rib fracture due to trauma and found increasing extrathoracic complication rates with an increase in the number of rib fractures. The extrathoracic complications were often pulmonary in nature (83% of cases with rib fractures) and included hemothorax, pneumothorax, hemo-pneumothorax, pneumonia, atelectasis, and adult respiratory distress syndrome (ARDS) [2-3]. Associated extrathoracic injuries, other than pulmonary complications, often include intra-abdominal organ injuries (29% of cases with rib fracture) [3]. The most common of these injuries include liver and spleen injuries. Sheiwki et al (2001) reported a significant correlation between any rib fractures on the right side or any lower rib fracture with liver injury. The same was reported for spleen injury with respect to the left side and these findings supported those reported by Clark et al (1988) [4,6]. Lee et al (1990) computed relative risk values corresponding to the probability of liver or spleen injury with respect to those who did and did not sustain rib fractures as the result of trauma. They reported that with the presence of three or more rib fractures, a relative risk value of 3.6 applied to liver injuries and 6.2 for spleen injuries [7].

Automobile crashes often involve the transfer of large amounts of energy that must be dissipated throughout the vehicle and the occupants. Later model vehicles have incorporated countermeasures to help transfer the energy to regions of the vehicle or occupant that will reduce injury risks. Often, the chest absorbs energy when loaded by the seatbelts and airbags. These loading situations can produce rib fractures, which themselves can be serious in nature [2-3]. Also, extrathoracic injuries, such as those stated previously, can be the result of a direct injury from the rib fractures, whether from the excess intrusion of the ribs or laceration from the fractured rib. However, it is hard to analyze this relationship

separately due to the difficulty in ascertaining whether the rib fractures and associated organ injuries are cause and effect in nature or merely due to a synergistic association [8].

Objective

The goal of this paper is to determine whether an association exists between rib fractures and lung, liver, and spleen injuries in MVCs.

METHODS

The National Highway and Traffic Safety Administration (NHTSA) maintains a database containing a sampling of all tow-away crashes in the United States known as the National Automotive Sampling System Crashworthiness Data System (NASS/CDS) which investigates roughly 5,000 crashes per year. Weights are applied to each investigated crash to create a representation of all crashes in the United States. The data for this paper was extracted from NASS/CDS and the results were compiled using SAS (SAS Institute, Cary, NC). The cases analyzed from this dataset were restricted to belted drivers and right front seat passengers who were involved in crashes where the most harmful event was either a frontal or side collision. Cases with a rollover event were excluded. Finally, only vehicle model years of 1998 and greater were included. A federal mandate was instituted in 1998 that required that all vehicles sold in the United States meet the new requirements for the de-powering of frontal airbags. NASS/CDS case years 1998-2006 were used in this investigation. As a result, a population size of just under seven million occupants was used in this study.

All reported injuries are categorized using the Abbreviated Injury Scale (AIS). AIS ranks injury severity by threat to life using a six-level scale where 0 = no injury and 6=fatal injury [9]. Based on the cases that meet the above restrictions, this analysis looks specifically at the rib fracture side and its relation to organ injury as follows:

- Lung injuries associated with any rib fracture
- Spleen injuries associated with left or bi-lateral rib fractures
- Liver injuries associated with right or bi-lateral rib fractures

NASS/CDS does not provide information regarding which rib(s) are fractured, so a more in-depth analysis of this nature is not possible.

All averages and confidence intervals are based on weighted data. The confidence intervals are created using a binomial distribution. All significance tests are performed using a two-sample test of proportions. The total number of injuries for each organ is given in Table 1.

Table 1: Distribution of occupants for each organ injury with and without rib fracture (unweighted).

	TOTAL INJURY	INJURY W/ RIB FRACTURE
LUNG	339	246
LIVER	196	71
SPLEEN	203	68

RESULTS

Thoracic injuries make up a large fraction of all serious injuries in automobile accidents. As shown in Figure 1 and Figure 2, chest injuries comprise roughly one quarter and one third of serious injuries in frontal and side crashes, respectively.

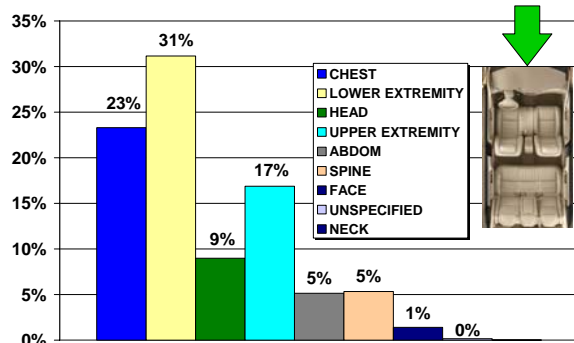


Figure 1: Distribution of AIS3+ injuries by body region in frontal crashes (weighted).

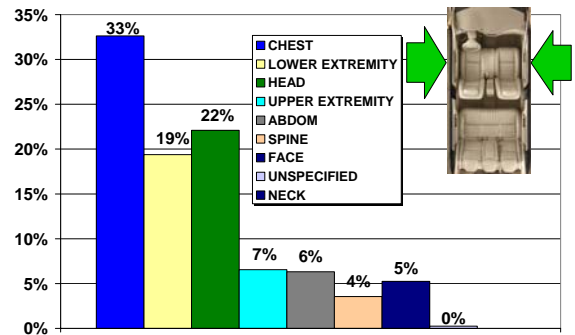


Figure 2: Distribution of AIS3+ injuries by body region in Side crashes (weighted).

The risk of organ injury with rib fracture, varies by crash mode. For all frontal and side crashes, it was shown that lung injuries occur in 13% of rib fracture cases, spleen injuries in 5% of cases and liver injuries in 2% of cases. Figure 3 illustrates that spleen and liver injuries are infrequently associated with rib fractures in frontal crashes alone while Figure 4 reveals that spleen ($p < 0.001$) and lung ($p < 0.001$) injuries are much more common in all side impacts where associated rib fractures have occurred. Liver injuries are also significantly more common in side crashes where an associated rib fracture has occurred, but the difference is not as severe ($p < 0.001$).

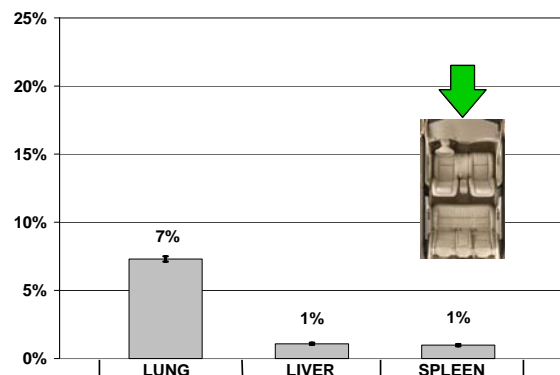


Figure 3: Risk of an AIS2+ organ injury given the presence of a rib fracture in frontal collisions (weighted).

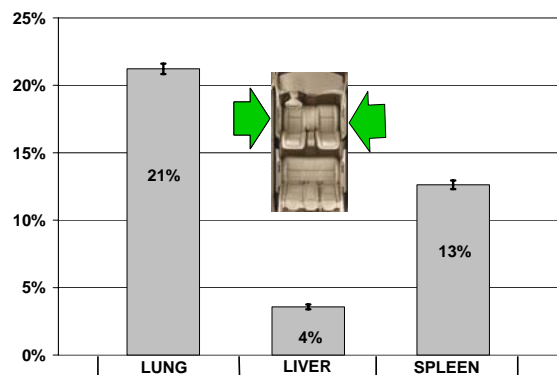


Figure 4: Risk of an AIS2+ organ injury given the presence of a rib fracture in side collisions (weighted).

In side crashes there is frequently a relationship between the direction of impact and the injured organ. Figure 5 shows that the impacted side of the vehicle in near-side crashes relates to the location of the injured organ. Near side impacts are defined as cases where the occupant is seated on the struck side of the vehicle. For both the driver and right front passenger in near-side impacts, lung injuries exist with the presence of rib fractures at relatively high frequencies. The spleen is more often injured in near-side

crashes for the driver with an associated rib fracture ($p < 0.001$), corresponding to the location of the organ in the body. Conversely, the liver is more often injured in near-side collisions for the right front passenger with an associated rib fracture ($p < 0.001$), also corresponding to the position of the organ in the body.

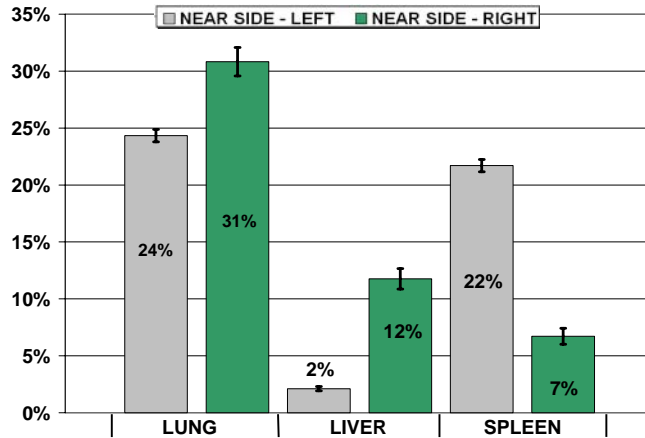


Figure 5: Distribution of AIS2+ organ injuries given the presence of rib fractures in near-side crashes (weighted).

Analyzing the rate of occurrence of an associated rib fracture for a given organ injury provides a different perspective on the issue. Given that there was an AIS2+ lung injury, Figure 6 shows that there are not associated rib fractures in the majority of all frontal crashes. However, Figure 7 shows that in near-side crashes 18% of AIS2+ driver liver injuries had corresponding rib fractures compared to 58% of AIS2+ liver injuries for the right front passenger. Of all AIS2+ spleen injuries, 21% in near-side crashes for the right front passenger compared to 85% of near-side crashes for the driver had corresponding rib fractures. Both organ injury modalities again correlate with the location of the organ within the body.

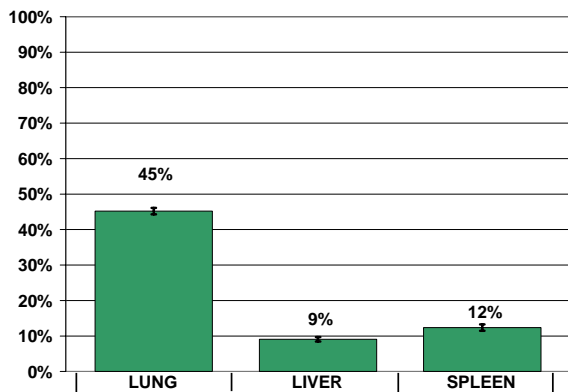


Figure 6: Risk of rib fracture given an AIS2+ organ injury in frontal crashes. (weighted).

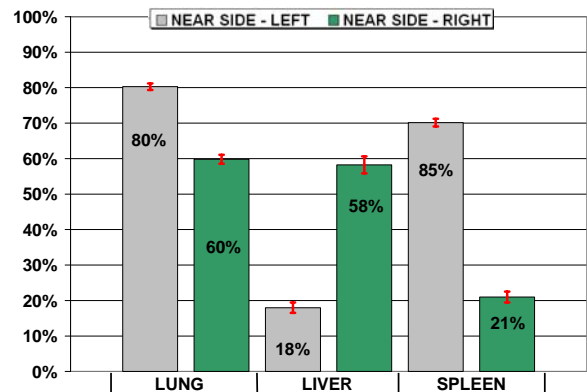


Figure 7: Risk of rib fracture given an AIS2+ organ injury in near-side crashes. (weighted).

Table 2: 2x2 contingency test table test utilizing chi-square to test for independence between organ injuries and associated rib fractures in frontal crashes (weighted).

		No Fracture	Fracture	
Lung	No Injury	4,692,258	66,962	p-value < 0.0001
	Injury	6,398 0.14%	5,276 7.30%	
Liver	No Injury	4,697,514	65,489	p-value < 0.0001
	Injury	7,175 0.15%	717 1.08%	
Spleen	No Injury	4,700,103	65,557	p-value < 0.0001
	Injury	4,586 0.10%	648 0.98%	

Table 3: 2x2 contingency test table test utilizing chi-square to test for independence between organ injuries and associated rib fractures in near-side crashes (weighted).

		No Fracture	Fracture	
Lung	No Injury	1,067,365	21,449	p-value < 0.0001
	Injury	2,496 0.23%	7,350 25.52%	
Liver	No Injury	1,069,265	25,823	p-value < 0.0001
	Injury	2,532 0.24%	1,041 3.88%	
Spleen	No Injury	1,068,530	21,767	p-value < 0.0001
	Injury	3,267 0.30%	5,097 18.97%	

The contingency test results shown in Table 2 and Table 3 reveals that there indeed maybe a significant difference between the organ injuries with and without rib fractures for occupants in frontal and near-side crashes. A contingency test was performed for all impact modes of interest and the results showed the possibility of a significant relationship between organ injury and the associate rib fractures for each mode.

DISCUSSION

The results of this analysis show a number of patterns in the modes of organ injury in relation to rib fractures in vehicle crashes. Figure 3 shows that rib fractures in frontal crashes often do not have a concomitant organ injury. Figure 4 reveals that lung injuries and spleen injuries with associated rib fractures occur at a higher rate in side crashes than in frontal collisions ($p < 0.001$). Frontal crashes allow for significantly more energy absorption via the crumple zone at the front of the vehicle, the seatbelts and the frontal airbags. Also, improvements in restraint and occupant protection performance in recent years have increased significantly. This may explain the differences between the study by Shorr et al in 1987 that reported extrathoracic injuries in 29% of cases with rib fracture and this study that reported organ injuries in 15% of cases with a rib fracture. The side on which the vehicle was struck remains an

important risk factor for liver and spleen injuries. Shweiki et al (2001) and Clark et al (1988) described a relationship between the side of impact and the organ that is most often injured as a result of the insult [4, 6]. Figure 5 illustrates the predominance of spleen injuries in near-side impacts for the driver and for liver injuries with respect to the right front passenger when there is a rib fracture. However, Figure 4 and Figure 7 expresses that in side impacts, spleen injuries with associated rib fractures are more common than for liver injuries.

The contingency test results expressed in Table 2 and Table 3 reveal that there is indeed a relationship between organ injuries and associated rib fractures in all crash modes of interest. All three organs of interest presented a p-value < 0.001. From this it is possible to show that in cases of no rib fracture, it is a less likely that an organ injury will occur. Alternatively, when a rib fracture does occur, there is a significantly greater chance that an associated organ injury will occur. It should be noted that the majority of crashes do not result in injury. Because the organ injuries with no associated rib fracture are with respect to all occupants, a very small percentage of organ injuries without rib fracture are presented.

The relationships expressed in this report reveal that organ injuries often occur with associated rib fractures, but it does not explain the source of these relationships. It is unknown how much of the relationship can be attributed to a cause and effect scenario. The correlation may be the result of crash severity alone. A crash event severe enough to cause a rib fracture may be sufficient for an organ injury to occur separately.

CONCLUSIONS

The relationship between organ injury and associated rib fractures is a function of crash mode. Also, a significant difference exists between organ injuries with associated rib fractures compared to those without fracture, implying that the presence of rib fracture is a good indicator of organ injury.

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