THE ASSOCIATION BETWEEN AGE, INJURY, AND SURVIVAL TO HOSPITAL AMONG A COHORT OF INJURED MOTORCYCLISTS

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ABSTRACT

Despite the significant increase in mortality among older motorcyclists during the past decade, few studies have addressed specific injuries or mortality rates among all those injured. The purpose of this study is to describe the crash and injury characteristics among a cohort of motorcyclists injured in Maryland, and to determine the influence of age and crash type on mortality, injury patterns, and place of death (scene vs. hospital). Possible biases introduced by studying only those hospitalized are described. Based on the findings, specific injury prevention strategies for older vs. younger riders are proposed.

Over the past decade there has been a striking increase in the fatality rates among motorcyclists. This increase has been especially notable among older riders (40+), despite the fact that exposure data shows a lower crash risk among this group. Previous studies have shown both decreased crash rates and increased injury rates among older motorcyclists [Haworth, 2004; Mulvihill and Haworth, 2005]. Although fatalities have increased in all age groups, the largest increase has been in the group of riders over the age of 49. According to The National Highway Traffic Safety Administration’s (NHTSA) National Center for Statistics and Analysis, in 1995 older riders accounted for 25% of deaths, but this proportion had grown to 47% for 2005 [NHTSA, 2006].
Stutts et al. examined trends in motorcyclist deaths registrations, and crash rates from 1990-2002 in North Carolina (2004). During this period the numbers of motorcyclists 35 and older increased. In addition, significant differences in the crash patterns of older and younger motorcyclists were noted, with older motorcyclists crashing more often on high speed roadways and in rural areas, having fewer run-off-road events, being involved in fewer single vehicle crashes, having more crashes at intersections, and having more alcohol/drug involvement.

Despite the burden of injury associated with motorcycle crashes, few comprehensive studies have been conducted to examine the types of injuries sustained by hospitalized motorcyclists [Begg et al., 1994]; instead, most studies have focused primarily on fatalities, comparing riders with and without helmets, and trends in head injury following repeal or passage of motorcycle helmet laws. Other studies have examined specific injuries but did not take into account the ages of the motorcyclists [Sarkar et al., 1995; Kraus et al., 1994; Ankarath et al., 2002].

In addition, no national data on injuries to motorcyclists are currently available to address this problem. Data in NHTSA’s Fatality Analysis Reporting System (FARS) include a census of motorcyclist fatalities but provide no data on injuries. NHTSA’s National Automotive Sampling System (NASS) database, which is comprised of data from a nationwide sampling of crash-related injuries, does not include motorcyclists. Given this lack, there have been few reports of actual mortality rates among all injured motorcyclists, or the proportion of deaths that occur at the scene of the crash. Thus, there is a need for more research on the nature and severity of injuries to riders, the characteristics of the associated crashes, and the mortality rates, both at the scene and in-hospital for younger vs. older motorcyclists.

Previous research by Kraus et al. showed that the most common injury to the thorax was rib fracture; moreover, those with rib fractures were 13.9 times more likely to have an intra-thoracic injury of any severity, and 41.5 times more likely to have multiple thoracic injuries compared with riders with no rib fractures (2002). They also found that rib fractures were associated with the presence of multiple and/or severe abdominal injuries and that the odds of internal organ injuries increased with the number and bilaterality of rib fractures. However, the authors did not report on the relationship of age and thoracic injury in their population.

Kent et al. have reported that anatomic changes in the thorax associated with aging include changes in rib angles as well as bone
density (2005). It may be that these changes, in conjunction with
differences in crash types noted between the two age groups, may
contribute to the greater risk of rib fractures in the older group. With
regard to the increased in-hospital mortality among older riders, there are
also physiologic changes in pulmonary compliance that could increase
the risk of mortality following serious thoracic injury.

In a previous paper [Dischinger et al., 2006] we presented data
on all injured motorcyclists admitted to Maryland hospitals during the
period 1998-2002. The incidence of thoracic injury was noted to be
significantly higher in older (age 40+) hospitalized riders. However, no
data on scene fatalities were included, which could result in a bias with
respect to the injury and crash characteristics observed.

The purpose of this analysis, based on hospital admissions and
fatalities between 1999 and 2001, is to contrast injury patterns, crash
characteristics, and mortality in a population of injured motorcyclists,
including those admitted to the hospital and those who died before
hospitalization.

METHODS

Data from the Crash Outcome Data Evaluation System
(CODES) project were obtained for all injured motorcyclists hospitalized
in the state of Maryland between 1999 and 2001. These data are based
on a linkage of police crash reports from the Maryland Automated
Accident Reporting System (MAARS) and the Health Services Cost
Review Commission (HSCRC). The uniform hospital discharge abstract
data were obtained from all 52 non-federal acute care hospitals in the
state. However, this estimate excludes outpatient cases.

These data were then linked, using probabilistic linkage
techniques [McGlincy, 2006] to obtain information on all hospitalized
motorcyclists within the state. Data on fatalities were then obtained from
the Office of the Chief Medical Examiner for the state of Maryland
(OCME), by manual abstraction and coding of autopsy reports. Every
autopsy contained a detailed list of injuries suffered by the occupant.
Most records also contained an investigation report that detailed each
injury further.

Older motorcyclists were defined as those aged 40 years or
greater. Data on crash characteristics were obtained from the police crash
reports. No details regarding the types of helmets used were available,
but helmet use (yes/no) was obtained from the police crash reports.
Engine size was determined using a program that utilized the vehicle
identification number (VIN) of the motorcycle [Polk, 2004]. Engine
sizes were grouped into two categories (<1000cc vs. 1000+ cc) in accordance with NHTSA data showing that the mean engine size among motorcyclist fatalities was 999cc during 2002.

Data on injuries were obtained from hospital discharge records, which provide ICD-9 (International Classification of Diseases, 9th edition) codes for specific injuries. In order to obtain injury severity scores (ISS), these diagnoses were first translated into Abbreviated Injury Scores (AIS). The AIS divides injuries by body region, structure injured, and the nature and severity of the injury.

Toxicology data on blood alcohol concentration (BAC) were available for all motorcyclists admitted to the R Adams Cowley Shock Trauma Center in Baltimore. In addition, BAC data were obtained on fatal cases from the Office of the Chief Medical Examiner for the state of Maryland. This BAC data, provided at time of autopsy, will be interpreted with caution because blood may not be obtained from intact vasculature i.e. pleural fluid is sent for toxicology.

Injury coding for the fatal cases presents a challenge. For those riders that die at the scene of the crash and are not admitted to the trauma center, their autopsy records will be obtained from the OCME. Using those reports, injuries will be coded using ICD-9 and AIS coding. However, the severity of injuries will be difficult to capture accurately due to the nature of the autopsy report itself. Usually, injuries are not described in the detail needed to accurately code their severity. For example, an autopsy may describe a significant liver laceration without explaining the depth or size of that injury. In this case, the injury may be undercoded, assigned a lower severity, because it is difficult for the researcher to ascertain the extent of the damage. Also, almost all autopsies list cause of death as multiple injuries, accident, etc. instead of something specific such as grade V liver laceration or transected ascending aorta. Therefore it is difficult to identify a single injury that caused the death when, most often, the occupant suffered numerous fatal injuries. Therefore, injury coding for those that enter a trauma center will be more accurate than those that died at the scene, but those fatalities will be analyzed with this understanding.

RESULTS

There were a total of 865 injured motorcyclists during this time period, including 128 fatalities, with linked injury data, either from hospital discharge records or autopsy reports. From the police report,
1,041 motorcyclists were indicated to have had an “incapacitating” (KABCO=4) or fatal (KABCO=5) injury. Of this group, successful linkage with a hospital record or autopsy report was achieved for 865 (83%).

Table 1 shows the demographic and crash characteristics of the population. Of the total cases, approximately two thirds were less than 40 years of age, and the majority (95%) were men. The median ISS score was 9, for both groups. Overall, the mortality rate was 14.8%, and while younger riders had a higher mortality rate, the difference was not statistically significant.

| Table 1 – Characteristics of Motorcyclists by Age |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Total (N=865) % | Age<40 (n=587) % | Age 40+ (n=278) % | p Value         |
| Male             | 95              | 96              | 93              | 0.06            |
| Died             | 14.8            | 16.1            | 12.2            | NS              |
| Median ISS       | 9               | 9               | 9               | NS              |
| Helmeted *       | 85              | 82              | 91              | <0.001          |
| Engine <1,000 cc | 62              | 77              | 32              | <0.001          |
| BAC+             | 26              | 25              | 27              | NS              |
| Median BAC Level (mg/dl) (25th – 75th) | 140 (84-190) | 130 (78-176) | 172 (99-220) | 0.068 |

Crash Type

<table>
<thead>
<tr>
<th></th>
<th>Total (N=865) %</th>
<th>Age&lt;40 (n=587) %</th>
<th>Age 40+ (n=278) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other vehicle(s)</td>
<td>47</td>
<td>50</td>
<td>42</td>
</tr>
<tr>
<td>Fixed Object/Parked Vehicle</td>
<td>29</td>
<td>31</td>
<td>24</td>
</tr>
<tr>
<td>Overturn</td>
<td>9</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Other**</td>
<td>14</td>
<td>12</td>
<td>19</td>
</tr>
</tbody>
</table>

* There were 14% cases with unknown helmet use among both age groups.
** Other crash type includes collisions with animals and other objects.

Helmet usage was high overall (85%), but older riders were significantly more likely to be wearing a helmet, as opposed to the younger group (91% vs. 82%, p<.001). In addition, older riders were significantly more likely to ride motorcycles with engine sizes of 1000 cc or greater (77% vs. 32%, p<.001).

For both groups, the primary crash type was collision with another vehicle, followed by crashes involving fixed objects. However,
older riders had significantly more collisions involving overturns or collisions with other objects such as embankments or with animals.

BAC levels were available for 444 (51%) of the riders. Approximately one fourth of each group had positive BAC levels at the time of the crash. Among those with positive BACs, the overall median level was 140 mg/dl, considerably higher than the legal limit of 80 mg/dl. The median level for older riders was considerably higher than that for the younger group (172 vs. 130 mg/dl). Drinking riders had a significantly higher incidence of fixed object crashes (43.4% vs. 24.2%, p<.001). Furthermore, among intoxicated riders in fixed object crashes, mortality was significantly higher in younger, but not older, motorcyclists. The median ISS for drinking vs. non-drinking drivers was 17 vs. 9.5, p = 0.01. For younger riders the ISS for those intoxicated vs not intoxicated was 17.5 vs 9.0, p = 0.02; for older riders the median ISS for those drinking was 15.5 vs. 10 p= 0.3 (data not shown).

Overall there were 128 fatalities, the majority (79%) occurring at the scene of the crash; 27% of the deaths were older riders. Scene deaths were considerably higher among younger riders. As shown in Figure 1, almost half of the deaths to older riders occurred in the hospital, whereas only 11.7% of the younger fatally injured group survived until hospitalization.

Figure 1 - Distribution of Outcome by Age

![Figure 1](image)

Table 2 shows the median ISS score by age group and outcome disposition for younger vs. older riders. It is apparent that older riders
who died had significantly lower ISS scores than the younger group (38 vs. 48 median age).

Table 2 - Median ISS by Age Group and Disposition

<table>
<thead>
<tr>
<th></th>
<th>Age &lt;40</th>
<th>Age 40+</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survived [median (q1-q3)]</td>
<td>6 (4-13)</td>
<td>9 (4-17)</td>
<td>0.18</td>
</tr>
<tr>
<td>Died at the Scene [median (q1-q3)]</td>
<td>50 (33-75)</td>
<td>42 (38-50)</td>
<td>0.18</td>
</tr>
<tr>
<td>Died at Hospital [median (q1-q3)]</td>
<td>25 (13-50)</td>
<td>25 (16-37)</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Figures 2a and 2b show the distribution of injury types by age of the rider, comparing those who were hospitalized and those who died at the scene. Overall, the most prevalent injuries were those to the upper and lower extremities, followed by thoracic and head injuries. Several differences by age group were apparent. For the hospitalized group, younger riders had higher rates of spinal injury, though not statistically significant. In addition, while no differences in the rate of thoracic injury were noted by age among the dead at scene group, for those hospitalized older riders had significantly higher rates. There were no statistically significant differences in the rates of head injury by age, either among those who died at the scene or those who survived until hospitalization.

Figure 2a – Distribution of Injury by Age and Survival to Hospital
As shown in Figure 3, younger riders had higher mortality rates than older riders, even after controlling for engine size, overturn crashes, positive BAC levels and helmet use.

Differences in death rates and place of death were also apparent when comparing younger and older riders by motorcycle engine size, as
seen in Figure 4. Among younger riders, death rates were similar regardless of type of motorcycle; for older riders, on the other hand, those with larger engines had a mortality rate approximately four times greater than that of older riders with smaller engine vehicles.

Figure 4 - Mortality Rates by Age, Engine Size and Place of Death

Further analyses, shown in Table 3, reveal the differences in the thoracic injury diagnoses between the two groups. Younger riders had a higher incidence of injuries to the heart, lung and thoracic blood vessels, whereas older riders had significantly more rib fractures. The category ‘Heart / Lung Injury’ contains injuries to those organs including contusions and lacerations. The majority of the injuries in this group were to the lung; however there were a number of heart injuries as well. The category ‘Thoracic Vessels and Other Organs’ primarily contain injuries to the thoracic aorta, pulmonary vessels, etc.

Table 3 - Types of Thoracic Injuries by Age

<table>
<thead>
<tr>
<th></th>
<th>Age &lt;40</th>
<th>Age 40+</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 Rib Fractures</td>
<td>19.8</td>
<td>32.2</td>
<td>0.02</td>
</tr>
<tr>
<td>3+ Rib Fractures</td>
<td>38.4</td>
<td>47.8</td>
<td>NS</td>
</tr>
<tr>
<td>Pneumo / Hemothorax</td>
<td>50.3</td>
<td>50.0</td>
<td>NS</td>
</tr>
<tr>
<td>Heart / Lung Injury</td>
<td>61.6</td>
<td>44.4</td>
<td>0.008</td>
</tr>
<tr>
<td>Thoracic Vessels and Other Organs</td>
<td>32.8</td>
<td>10.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Spinal Cord Injury</td>
<td>7.9</td>
<td>1.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Upper Chest and Vertebral Fractures</td>
<td>13.6</td>
<td>15.6</td>
<td>NS</td>
</tr>
</tbody>
</table>
DISCUSSION

Fatalities to older riders represented approximately 26% of the total deaths in this Maryland population. While this is a significantly smaller proportion than the 47% reported by NHTSA, perhaps it is because Maryland has a helmet law, and the majority of riders in both groups were helmeted. Currently in the U.S. 20 states and Washington DC have comprehensive (all-rider) laws; the remainder have either no law or laws only applying to minors. Thus, the majority (60%) of older riders are not required to wear helmets.

Helmet use did not seem to be a significant factor in the age/mortality differential. Since helmets were worn by most riders, no association between helmet use and death was noted. However, no data on the types of helmets worn are available, since this information is not captured on the police report; it is possible that, despite similar usage rates by younger vs. older riders, the quality of the helmet used by the two groups could differ.

Key information regarding the speed of the crashes is not available; travel speed is not captured on the report. Analyses of data by speed limit show that older riders are traveling in higher speed zones. However, no actual data on travel speed is available from the police report. Although the assumption is made that the younger riders are traveling at higher speeds and are therefore more likely to die at the scene, data are not available to confirm this hypothesis. This theory is bolstered, however, by data on the types of injuries. Younger riders had more serious thoracic injuries, such as injuries to the heart or aorta, while older riders had more rib fractures and hemothoraces.

Although thoracic injuries are higher in the older vs. the younger group among riders who are hospitalized, when those dying at the scene are also included in the analysis this difference disappears.

In further examining the type of thoracic injury by age, the different distribution of rib fractures versus heart-blood vessel injuries suggests differences in the mechanisms causing these injuries in different age groups. Typically, very high energy (i.e. high speed or high delta V) is required to cause injuries to main blood vessels within the chest [Siegel et al., 2004] in the young. On the other hand, because of changes in the characteristics of the ribcage, much lower energy is required to cause rib fractures in the older individuals.

These suggested mechanistic differences may also explain the differences in relation to the site of death. Heart and blood vessel injuries are more likely to cause immediate death at the scene by
exsanguination or pump failure, in both the young and the elderly. Rib
fractures, however, are unlikely to cause death in the young, and less
likely to cause death immediately in the older rider. Nevertheless rib
fractures are known to have higher mortality among older persons with
injuries, but due to later pulmonary and infectious complications.

Our toxicology findings are similar to the findings by Luna et al
(1984). We found a higher ISS and mortality among the intoxicated
riders, with more of this group involved in fixed object crashes. While
BAC+ incidence was similar by age groups, our population showed a
higher mean BAC among the older riders. Subgroup analysis by age
showed that the difference in ISS between intoxicated and non-
itoxicated drivers is limited to the younger group. This latest fact
together with the finding of a higher mortality among the younger
intoxicated riders in fixed object crashes, implicates the speed of the rider
more than the age or the alcohol level as the responsible causal factor.
This is further supported by the lack of difference in ISS by alcohol
toxicology among fatally injured or surviving riders (data not shown).

Limitations of the study are related to the nature of the database.
Because of the intricacies of probabilistic linkage, a small number of
non-fatal cases may not be represented. Also, while CODES includes
data on hospitalized and dead patients, injured individuals who did not
receive treatment or were treated in the emergency room or at a private
office will be missing. Due to triaging rules, the older individuals are
more likely to be taken to a hospital. In addition, the sources of
information for injury scoring for patients seen at hospitals (clinical,
intra-operative and imaging) differ from the individuals dying at the
scene (autopsy) making comparisons across those groups by ISS score
less reliable.

SUMMARY / CONCLUSIONS

Mortality rates for the total population of riders did not vary
significantly by age; 16% of younger vs. 12% of older riders were fatally
injured. With respect to injury type, there were a few differences,
namely that younger riders had more spinal injuries, and older riders who
were hospitalized had more thoracic injuries. In addition, the median ISS
for fatally injured riders was significantly lower among the older group.

The majority of riders who were fatally injured died at the scene
of the crash. However, the proportion of scene deaths was significantly
higher for the younger group, while older riders were more likely to
survive until hospitalization.
Although the BAC+ rates were similar for the two groups (approximately 25%), the BAC levels were significantly higher among the older riders (median 170 vs. 130). For younger riders, those with positive BACs had higher death rates, but no differences were noted for older riders with and without positive BAC findings.

These findings suggest different injury prevention strategies for younger vs. older riders. Since most of the fatalities among the younger group occurred at the scene of the crash, this would suggest the need for primary prevention strategies, such as efforts to reduce speeding. For the older group, on the other hand, almost half of those who ultimately died survived until hospitalization, suggesting other possible secondary and tertiary prevention measures in addition to reductions in pre-crash alcohol consumption. Perhaps older riders are dying with less severe injuries due to pre-existing medical conditions that may, in turn, predispose them to more serious medical complications.

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