Risk of Injury Associated with the Use of Seat Belts and Air Bags in Motor Vehicle Crashes

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Abstract

Although air bags have been reported to reduce passenger mortality in frontal collisions, they have also been reported as a cause of injury in motor vehicle collisions (MVCs). The purpose of this study was to evaluate a large cohort of patients involved in MVCs to determine mortality and the pattern of injuries associated with seat belt use and air bag deployment. Information on patients involved in MVCs from 1988 to 2004 was obtained from the National Trauma Data Bank (NTDB). The data was evaluated based on four groups of safety devices: seat belt and deployed air bag (SBAB), seat belt only (SBO), deployed air bag only (ABO), and no safety devices (None). A total of 35,333 patients met study inclusion criteria. Air bags and seat belts used in combination decreased the risk of potentially fatal injuries, but increased the risk of lower extremity injuries (odds ratio, 1.35). The use of any type of restraint led to a decrease in the risk of injury or mortality in MVCs. Only half of all individuals in this study used any type of restraint device, which indicates the need for significant improvements in public health and safety seat belt utilization programs.

Mortality from motor vehicle collisions (MVCs) has steadily declined over the past 30 years and reached an all time low, in 2003, of 1.48 deaths per 100 million miles of vehicle travel in the United States.1 Seat belts have been identified as a significant contributor to this trend, but opinion regarding the benefits of air bags is in a state of flux. Mortality reduction in collisions with air bag deployment has been estimated to be as high as 25% to 30% in frontal crashes,2-7 although recent studies have reported a reduction in mortality risk of less than 10%.8

Despite the possible reduction in mortality with air bag use, concern still remains that air bag deployment may also inflict injury during an MVC. Multiple case studies in the literature report injuries attributed to air bag deployment,9-14 and several recent studies using larger patient cohorts have shown increased risk of upper and lower extremity injuries when air bags deploy.6,15-17 One criticism of prior studies demonstrating increased morbidity with air bag deployment is that the air bag deployment may affect the way crashes are characterized. For example, when characterizing crashes using the maximum abbreviated injury scale (MAIS) score, a crash where an air bag did not deploy may have an abbreviated injury scale (AIS). In a crash with an AIS 4 thorax injury and an AIS 3 lower extremity injury, the crash would be characterized as an MAIS 4 torso injury event. If a similar crash occurred where an air bag did deploy, the thorax injury may be reduced to an AIS 2, but the lower extremity injury remain an AIS 3. Now, the crash would be characterized as an MAIS 3 lower extremity event, which is due to the protective effect of the air bag in the thorax region and not due to increased injury from air bag deployment.

The purpose of this study was to evaluate a large cohort of patients who were involved in MVCs and assessed in the emergency department in order to determine the effect of seat belts and air bags, both in combination and independently, on the risk of injury to individual body regions of both drivers.
and passengers.

Materials and Methods

Data Source
The data for this study were obtained from the National Trauma Data Bank (NTDB), Version 4.1. Reporting of data to the NTDB is voluntary. The database is managed through the American College of Surgeons (ACS), and includes data from 55% of all level I trauma centers, 35% of level II trauma centers, and many level III trauma centers throughout the U.S. Version 4.1 includes approximately 1.12 million trauma cases from 377 institutions gathered from 1988 through 2004.

Target Population
The cohort of patients for this study was identified by reported mechanism of injury (e-codes), which identified the patient as having been involved in an MVC. Single car and multiple car accidents were included in the cohort and involved both collisions and rollover accidents. Crashes of vehicles other than passenger cars and light trucks as well as those involving pedestrians were excluded.

Restraint use was measured by the safety device variable, which indicated seat belt use, air bag deployment, or no devices being used. Occupants that were coded for other safety devices, such as helmets, protective clothing, or eye protection, were excluded from the analysis, as they may represent special cases of MVC, for example, a race car crash. Infant seats were also excluded from the analysis. Patients that were not coded for a safety device were excluded from the analysis due to uncertainty over whether no devices were used or the code for another safety device was not entered. AIS scores were used to identify injury to any of the eight body regions: head, face, neck, thorax, abdomen, spine, upper extremities, and lower extremities. Patients without complete AIS scoring data were excluded from the analysis.

Patient in-hospital mortality, age, gender, race, and driver-passenger status were also extracted from the database. Valid codes for all categories were required for inclusion in the final cohort; otherwise that person was excluded from the final analysis. Vehicle information, other than safety restraint device use, was not available from the database.

Defining Severity of Bodily Injury
Severity of bodily injury was based on AIS classification, which categorizes injuries as follows: (0) none; (1) minor; (2) moderate; (3) serious; (4) severe; (5) critical; and (6) maximum, an injury that is virtually unsurvivable. The information for scoring each particular injury was obtained from the AIS dictionary. Three separate definitions were developed to further evaluate whether safety restraint devices provided a greater protective effect as the severity of the injury increased. The definitions are as follows:

- AIS 2+ (moderate) was defined so that each body region was classified as either not injured if the AIS score was less than 2, or as a moderate to critical injury if the AIS score was 2 to 6;
- AIS 3+ (serious) was defined so that each body region was classified as either less than a serious injury if the AIS score was less than 3, or as a serious to critical injury if the AIS score was 3 to 6; and
- AIS 4+ (severe) was defined so that each body region was classified as either less than a severe injury if the AIS score was less than 4, or as a severe to critical injury if the AIS score was 4 to 6.

Analysis Plan
Preliminary analyses evaluated the incidence of safety device use relative to patient demographics of age, gender, race, and role (driver-passenger) in the MVC, as well as the incidence of severe injury rates across the eight body regions specified within the three AIS category guidelines indicated.

Logistic regression methods were used to model injury status (serious-not serious) based on each of the three proposed AIS classification definitions (moderate, serious, severe) at each body region. Patient age, gender, race, seat position (i.e., driver-passenger), and safety device employed were used to generate odds ratios that indicated the risk of injury in each body region for each safety device relative to no safety devices. These odds ratios were then adjusted for all other predictors to evaluate the role that each safety device may have played in protecting against injury to the various body regions as the severity of the injury increased.

All analyses were performed using the SAS® statistical software package version 9.1 (SAS Institute, Cary, North Carolina) running under the Windows® XP operating system. In all analyses, a two-tailed type I error rate was set at .01 to infer statistical significance due to the large number of observations within the database.

Results
From 1988 to 2004, 220,000 of the more than 1.12 million patients entered into the NTDB were coded as being involved in an MVC. From this cohort of patients, those without complete AIS scoring data or missing safety restraint use information were excluded, resulting in a final cohort of 35,333 MVC occupants who were evaluated in a hospital emergency department.

Occupant characteristics within each of the four restraint use categories are summarized in Tables 1 and 2. Surprisingly, nearly half (47.5%) of all occupants coded for safety information were unrestrained. Occupants with deployment of an air bag alone or air bag deployment with the use of a seat belt accounted for less than 9% of the sample. Of those using safety devices, the vast majority used only a seat belt. The average age of those using no safety devices was substantially lower compared to the average age of patients who used some restraint device or devices, with those using seat belts plus air bags being oldest (44.5 years), followed
Males comprised 56% of the cohort, and 53.8% of males were unrestrained. In contrast, 60.6% of female patients used some type of restraint device, with most females using a seat belt alone (50.4%). The cohort was predominantly White (71.6%), with Blacks and Hispanics accounting for 16.6% and 7.8% of the sample, respectively. Safety device use within racial groups, although statistically significant at p < .0001, appeared to be roughly similar when all groups were compared. More than two-thirds of the occupants were drivers (68.1%), and most drivers used at least one safety device (seat belt only, 45.7%; air bag only, 3.3%; seat belt plus air bag, 7.1%).

**Patterns of Safety Device Effects across Risk Definitions**

Results using the AIS 2+, AIS 3+, and AIS 4+ severity definitions are summarized in Table 3.

### Table 1

**Safety Device Use Relative to Patient Age and In-Hospital Morality**

<table>
<thead>
<tr>
<th>Safety Device Use</th>
<th>None</th>
<th>SBO</th>
<th>ABO</th>
<th>SBAB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>16,779</td>
<td>15,573</td>
<td>943</td>
<td>2,038</td>
<td>35,333</td>
</tr>
<tr>
<td>(% of total)</td>
<td>(47.5)</td>
<td>(44.1)</td>
<td>(2.7)</td>
<td>(5.8)</td>
<td>(100)</td>
</tr>
<tr>
<td>Mean Age (SD)</td>
<td>32.7 (17.6)</td>
<td>39.7 (20.5)</td>
<td>37.8 (18.5)</td>
<td>44.5 (19.9)</td>
<td>36.6 (19.5)</td>
</tr>
<tr>
<td>In-Hospital Mortality</td>
<td>1037</td>
<td>560</td>
<td>56</td>
<td>66</td>
<td>1719</td>
</tr>
<tr>
<td>(% of total)</td>
<td>(6.2)</td>
<td>(3.6)</td>
<td>(5.9)</td>
<td>(3.2)</td>
<td>(4.9)</td>
</tr>
</tbody>
</table>

*None (No safety devices), SBO (Seat belt only), ABO (Air bag only), SBAB (Seat belt and air bag). † Age was significantly different across Safety Device Use categories, F_{3,35329} = 491.67, p < .0001. All means were significantly different from each other when alpha was set at .01 using Tukey’s Studentized Range Highest Significant Difference (HSD) pair-wise follow-up comparison procedure.

### Table 2

**Summary of the Distribution of Safety Device Use across the Categorical Predictors**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>N (%)</th>
<th>Safety Device Use</th>
<th>χ²</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex: Female</td>
<td>15,548</td>
<td>None 6127, SBO 7842, ABO 433, SBAB 1146</td>
<td>761.92</td>
<td>3</td>
<td>.0001</td>
</tr>
<tr>
<td></td>
<td>[%] (44.00)</td>
<td>[39.41]</td>
<td>[50.44]</td>
<td>[2.78]</td>
<td>[7.37]</td>
</tr>
<tr>
<td></td>
<td>Male 19,785</td>
<td>None 10,652, SBO 7731, ABO 510, SBAB 892</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
</tr>
<tr>
<td></td>
<td>[%] (56.00)</td>
<td>[53.84]</td>
<td>[39.08]</td>
<td>[2.58]</td>
<td>[4.51]</td>
</tr>
<tr>
<td>Race: White 25,295</td>
<td>None 11,963, SBO 11,042, ABO 711, SBAB 1579</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (71.59)</td>
<td>[47.29]</td>
<td>[43.65]</td>
<td>[2.81]</td>
<td>[6.24]</td>
</tr>
<tr>
<td></td>
<td>Black 5876</td>
<td>None 2708, SBO 2692, ABO 164, SBAB 312</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
</tr>
<tr>
<td></td>
<td>[%] (16.63)</td>
<td>[46.09]</td>
<td>[45.81]</td>
<td>[2.79]</td>
<td>[5.31]</td>
</tr>
<tr>
<td>Hispanic 2766</td>
<td>None 1463, SBO 1198, ABO 33, SBAB 72</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (7.83)</td>
<td>[52.89]</td>
<td>[43.51]</td>
<td>[1.19]</td>
<td>[2.60]</td>
</tr>
<tr>
<td>Other 1030</td>
<td>None 443, SBO 510, ABO 23, SBAB 54</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (2.92)</td>
<td>[43.06]</td>
<td>[49.51]</td>
<td>[2.23]</td>
<td>[5.24]</td>
</tr>
<tr>
<td>Unknown 366</td>
<td>None 202, SBO 131, ABO 12, SBAB 21</td>
<td>133.19</td>
<td>12</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (1.04)</td>
<td>[55.19]</td>
<td>[35.79]</td>
<td>[3.28]</td>
<td>[5.74]</td>
</tr>
<tr>
<td>Role: Driver 24,076</td>
<td>None 10,600, SBO 10,990, ABO 786, SBAB 1700</td>
<td>552.52</td>
<td>3</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (68.14)</td>
<td>[44.03]</td>
<td>[45.65]</td>
<td>[3.26]</td>
<td>[7.06]</td>
</tr>
<tr>
<td>Passenger 11,257</td>
<td>None 6179, SBO 4583, ABO 157, SBAB 338</td>
<td>552.52</td>
<td>3</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[%] (31.86)</td>
<td>[54.89]</td>
<td>[40.71]</td>
<td>[1.39]</td>
<td>[3.00]</td>
</tr>
</tbody>
</table>

*None (No safety devices), SBO (Seat belt only), ABO (Air bag only), SBAB (Seat belt and air bag). † [%] Percent of patients in that predictor level (column sums to 100% within that category). ‡ [%] Percent of patients within the predictor level in the safety device category (row sums to 100% for the four safety device groups).

Risk Defined as AIS 2+

When individual body regions were analyzed, the seat belt only group showed a significant reduction in the risk of injury to all eight body regions. When an air bag deployed in combination with seat belt use, the risk of injury to the head, face, thorax, abdomen, and spine body regions was further reduced. The neck and upper extremities were not statistically different from an odds ratio of 1.0, and the lower extremities showed a significant increase in risk of injury for seat belts and air bags in combination (OR, 1.36).

Air bags deployed alone were associated with significant decreases in the risk of injury to the head, face, torso, and spine, but also showed a significant increase in the risk of lower extremity injury (OR, 1.345; 99% CI, 1.127 to 1.604), which was similar to observations in the air bag plus seat belt group. No difference was seen in the neck, abdomen, or upper extremity body regions when compared to no restraint devices.
When individual body regions were analyzed, the seat belt only group showed a statistically significant reduction in risk in every body region except neck. Air bag deployment in addition to seat belt use further reduced the risk of injury to all body regions, with the exception of the upper and lower extremities. In this risk group, seat belt use plus air bag deployment was not statistically different from no restraint use for both upper (OR, 1.145; 99% CI, 0.874 to 1.479) and lower (OR, 1.052; 99% CI, 0.897 to 1.229) extremities.

Air bags deployed alone resulted in a significant reduction in head (OR, 0.691; 99% CI, 0.544 to 0.868) and torso (OR, 0.790; 99% CI, 0.635 to 0.975) injuries, and once again significantly increased the risk of lower extremity injury (OR, 1.331; 99% CI, 1.078 to 1.633). The risk of upper extremity injuries was not statistically different from no restraints when air bags deployed alone (OR, 1.259; 99% CI, 0.865 to 1.774).

Risk Defined as AIS 4+

The seat belt only group significantly reduced the risk of injury to the head, torso, abdomen, spine, and lower extremities. The addition of air bag deployment to the use of a seat belt further reduced the risk of injury to the same regions as the seat belt only group, including the lower extremities (OR, 0.153; 99% CI, 0.021 to 0.520).

Air bag deployment alone significantly reduced the risk of head injury (OR, 0.570; 99% CI, 0.400 to 0.789), and again demonstrated no difference in the risk of lower extremity injury when compared to patients that did not use safety restraints (OR, 1.454; 99% CI, 0.627 to 2.890). Of note, there are no injuries to the upper extremity on the AIS that qualify as greater or equal to 4; thus, upper extremity injuries could not be analyzed.

Overall Mortality and Injury Risk

When injuries defined as AIS 2+ were considered, the risk of injury to any body region was significantly reduced in the seat belt plus air bag (OR, 0.705; 99% CI, 0.603 to 0.826; p < 0.001) and seat belt only groups (OR, 0.586; 99% CI, 0.543 to 0.631; p < 0.001), compared to no safety restraints, but not for the air bag only group (OR, 1.07; 99% CI 0.842 to 1.383).

When injuries defined as AIS 3+ were considered, the seat
Fewer studies exist that evaluate the effect of AIS 4+ lower extremity injuries that occurred. When injuries defined as AIS 4+ were analyzed, all safety restraint groups provided a greater reduction in the risk of sustaining any injury, compared to no safety restraints (seat belt only: OR, 0.523; 99% CI, 0.483 to 0.566; seat belt plus air bag: OR, 0.437; 99% CI, 0.362 to 0.564; air bag only: OR, 0.723; 99% CI, 0.573 to 0.904), demonstrating a significant reduction for all safety device combinations as the severity of the injury increased.

In-hospital mortality was highest in the unrestrained group (6.2%), followed by the air bag only group (5.9%), the seat belt only group (3.6%), and the seat belt plus air bag group (3.2%). The use of any safety restraint device resulted in a significant reduction in mortality, with seat belts plus air bags providing the greatest level of protection.

**Discussion**

This study evaluated the effect of safety restraint devices in preventing injuries of varying severity in patients transported to a trauma center following an MVC. The analyses demonstrated a statistically significant reduction in injuries to nearly all body regions when a seat belt was used alone relative to no safety device use. When an air bag deployed along with the use of a seat belt, the risk of injury was further decreased in most body regions, with the exception of the extremities. For AIS 2+ and AIS 3+ injuries, air bag deployment appeared to negate the protective effect of seat belt use on upper extremity injuries, resulting in an injury rate similar to that of occupants with no restraint use. Lower extremity injury risk actually increased for AIS 2+ injuries when seat belts were used and an air bag deployed. Air bags alone provided a significant reduction in head injuries of all severities, as well as a decrease in AIS 2+ and AIS 3+ torso and spine injuries. Similar to air bag deployment with seat belt use, air bag deployment alone increased the risk of AIS 2+ and AIS 3+ lower extremity injuries, while showing an increase in AIS 4+ lower extremity injuries that was not statistically significant, possibly due to the small number of AIS 4+ lower extremity injuries that occurred.

The decrease in injury risk for any body region with seat belt use was not surprising, as reduced risk of injury with proper seat belt use has been documented in multiple studies. Fewer studies exist that evaluate the effect of air bag deployment on injury pattern in vehicle occupants. The current study’s findings that air bag deployment, with or without seat belt use, appear to decrease the risk of head, thorax, and spine injuries is consistent with data reported by the National Highway Transit and Safety Authority (NHTSA), although McGwin and colleagues did not find a protective effect for these body regions when air bags deployed alone. These same investigators, however, did find an increase in AIS 2+ lower extremity injuries with air bag deployment alone, though they did not see an increase in AIS 2+ lower extremity injuries when seat belts were used in conjunction with air bag deployment, as was seen in the present data. Estrada and coworkers demonstrated an increase in tibia and fibula fractures (an AIS 3 injury) with air bag deployment alone, but a nonsignificant increase in these fractures when a seat belt was used in combination with air bag deployment. Prior laboratory studies have shown a similar risk of injury to the lower extremities with air bag deployment owing to a “submarining” effect. The “submarining” effect is due to the transfer of energy to the lower extremities when energy from a rapid deceleration force is dissipated from the head and torso by a deployed air bag, resulting in increased excursion of the pelvis and lower extremities under the air bag. Crandall and associates demonstrated a similar effect with cadavers and crash test dummies. Burgess and colleagues also concluded that air bags did not prevent lower extremity injuries in a study of 10 drivers involved in MVCs. In contrast, Loo and coworkers found a protective effect against lower extremity injuries when air bags deployed alone, although these results have not been reproduced in other studies.

The current study also demonstrated an increased protective effect of air bags as the severity level of injury increased for injuries to any body region. For air bags alone, the risk of injury to any body region decreased from an odds ratio of approximately 1.0 (no risk reduction) for AIS 2+ and AIS 3+ injuries, to an odds ratio of 0.72 for AIS 4+ injuries. A similar pattern was seen when air bags were used in conjunction with seat belts. The risk of injury to any body region decreased sequentially as the severity of injury increased: odds ratio of 0.71 for AIS 2+ injuries; odds ratio of 0.64 for AIS 3+ injuries; and an odds ratio of 0.44 for AIS 4+ injuries.

The protective effect of seat belts remained relatively constant for each injury severity category. Closer inspection of the data revealed that the change in the risk of sustaining injury to any body region with air bag deployment was mostly driven by the risk of lower extremity injury for each AIS category used in the analysis. For AIS 2+ and AIS 3+ injuries, the protective effects of air bags alone for the head, thorax, and spine were essentially negated by the increase in lower extremity injuries. A similar pattern was seen with seat belts used in combination with air bags. The decreased risk for injury to any body region that occurred with AIS 4+ injuries was also driven by the risk of sustaining a lower extremity injury, although it was significantly decreased at this severity of injury. This was likely due to the rarity of AIS 4+ lower extremity injuries seen in this cohort and also due to the fact that only two AIS 4+ lower extremity injuries are included in the AIS scoring system: an above knee amputation and a crushed pelvis. The risk of sustaining an above knee amputation or pelvic crush injury may not
be increased by “submarining” in the way that other lower extremity injuries are; thus, resulting in the protective effect seen with air bag deployment.

The effect of mortality on injury patterns has been a concern with prior studies evaluating injury patterns to various body regions. The criticism of prior studies has been that an increase in extremity injuries seen with air bag deployment could be the result of mortality prevention from air bag deployment, so more patients were being transported alive to the hospital for evaluation rather than dying at the scene. If this phenomenon were occurring, the risk of extremity injury may be artificially inflated. The current study attempted to address this concern by including injuries sustained by patients who died during their hospitalization as a result of their MVC. The mortality rate of 6.2% for occupants with no safety restraint devices was observed in this study, with a sequential reduction in mortality risk for the air bag only group (4% decrease), seat belt only group (42% reduction), and the seat belt plus air bag group (48% reduction). The decrease in mortality seen in the air bag only group is relatively low, but is consistent with recent estimates by Cummings and associates, who estimated a 4% to 12% decrease in mortality with air bag deployment in all types of crashes. The sequential decrease seen with each group is also consistent with reports from the NHTSA that estimated the effectiveness of seat belts and air bags in reducing mortality in MVCs. Although deaths at the scene were not accounted for in this study, the fact that the mortality reduction seen in this study was consistent with prior reports provides some reassurance that patients from the unrestrained group were not dying at the scene at a rate that was significantly higher than patients in the other safety restraint groups, which may artificially inflate the rate of injuries seen in the safety restraint groups.

The cohort in this study also had a surprisingly low overall use rate of safety restraint devices (52.5%). The NHTSA has reported a consistent increase in the use rate of seat belts by the general public, with rates greater than 85% being reported in surveys from some states. The relatively low use rate seen in this group may be due to several factors: 1. the data included in this study goes back to 1988, when the overall use was lower than it is today; 2. people that participate in higher risk behavior that leads to an MVC may be less likely to use safety devices; and 3. The NTDB is a voluntary reporting database, and bias toward the most severe accidents may be unintentionally introduced through this type of reporting system (minor accidents where occupants used restraint devices may not be reported). Other studies have also shown relatively lower seat belt use rates than those reported by the NHTSA.

The results of this study should be interpreted in light of several limitations that include a lack of specific crash data, such as speed and the direction of impact, as well as the size of the vehicles involved in the collisions. These parameters have been shown in prior studies to influence mortality rates. Despite not having these data available, these results demonstrated similar protective effects from seat belts and air bags, compared to prior studies. Although this study attempted to analyze all types of crashes by using air bag deployment as one of the parameters, this criterion may have resulted in selecting for head-on collisions since air bags were designed to deploy in this type of collision. Thus, the protective effect of air bags seen here may partially be the result of comparing head-on collisions to other types of crashes. These data also may not be truly representative of the U.S. population as a whole, since the majority of the hospitals that report to the NTDB are level I trauma centers. This circumstance may select for more severe crashes, which in turn may result in an underestimation of the true protective benefit of safety restraint devices. Also, the deployment of an air bag might have prevented serious injuries to the head, torso, or abdomen, but may not have prevented an injury to the lower extremities. The net result is an apparent increase in lower extremity injuries with air bag deployment when the air bags actually prevented further injury to other body regions. This certainly may be the case in some MVCs, but does not fully explain the significant overall increase (35%) in lower extremity injuries seen in the current study.

Another potential limitation is the AIS scoring system that was used to classify injury severity, especially when evaluating extremity injuries. The AIS scoring system was designed to classify injuries according to their relative threat to life, and nearly all extremity injuries are classified as an AIS 2 or 3. Thus, the AIS score does not necessarily correlate with disability sustained from the injury. For example, a closed femur fracture and an upper extremity amputation are both AIS 3 injuries, yet the long-term disability is very different for each one.

Conclusions

The results of this study are generally consistent with the existing literature that has demonstrated the effectiveness of seat belts in reducing mortality and morbidity in MVCs. Seat belts appear to provide protection from all types of injuries sustained in vehicle collisions. Air bag deployment seems to further augment the protective effect of seat belts for head, face, torso, abdomen, and spine injuries, but air bag deployment negates the protective effect of seat belts for upper extremity injuries while increasing the risk of lower extremity injuries. Air bag deployment alone demonstrated a similar pattern of decreased head, torso, and spine injuries with an increase in lower extremity injuries. Thus, the deployment of an air bag resulted in a trade-off of a slight decrease in mortality, head injury, torso injury, and spine injury for an increase in lower extremity injuries. This trade-off has led some investigators to advocate for air bags that can be disabled by the occupants. The current study supports the further development of knee bolster protection to help guard against the “submarining” effect that may be occurring with the current air bag systems. Automobile oc-
cupants should also be reminded that the use of seat belts provides the largest degree of protection against morbidity and mortality in MVCs.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References