AIR BAG RELATED INJURIES IN NHTSA’S CRASH DATABASES

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) has been monitoring and gathering information on air bag related injuries and fatalities in its data collection programs since air bags were introduced. As frontal air bag technology has progressed from barrier certified (a.k.a. first generation) to sled certified (a.k.a. redesigned) and to advanced certified air bag systems, there has been a drastic reduction in the number of injuries and fatalities attributed to these air bags. More recently developed air bags designed to protect occupants in side impacts and rollovers also do not appear to pose a serious threat. The purpose of this paper is to describe the evolution of air bag injuries in all types of air bags collected in NHTSA’s in-depth investigation and crash report based programs. Additionally, the paper discusses future plans for collection of air bag and injury information as NHTSA’s data collection programs are redesigned in the Data Modernization Project.

INTRODUCTION

Investigation-based programs are the only source of detailed information required to research the injury outcomes related to air bag deployments. NHTSA currently operates three investigation-based data collection programs with detailed air bag information; the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS), Special Crash Investigations (SCI) and the Crash Injury Research and Engineering Network (CIREN). Data from each of the programs has been critical in NHTSA’s evaluation of air bag performance. These data collection programs have somewhat different focuses, but also complement one another in different ways.

NASS-CDS is a nationally representative sample of towed light vehicle crashes with an emphasis on the crashworthiness of the vehicle. The case selection algorithm is designed to give fatal and severe injury crashes a higher probability of selection. Data is collected at 24 sites across the country with a yearly average of 4,500 cases per year since 1999. NASS-CDS data can be viewed clinically at http://www.nhtsa.gov/NASS. The yearly SAS data sets are available for statistical use at ftp://ftp.nhtsa.dot.gov/NASS/.

SCI is a collection of approximately 125-150 targeted investigations each year that are utilized by NHTSA and the automotive safety community to understand the real-world performance of existing and emerging advanced safety systems. Both the SCI case viewers and Technical Reports can be accessed at http://www.nhtsa.gov/SCI.

CIREN is a hospital-based study operating at six centers across the country, collecting approximately 300 cases per year. The CIREN process combines prospective data collection with professional multidisciplinary analysis of medical and engineering evidence to determine injury causation in every crash investigation conducted. CIREN data is available at http://www.nhtsa.gov/CIREN.

Although the programs have different overall objectives they are all modeled on the same data collection practices, procedures, and data structures. This consistency allows for researchers to quantify the relationship between vehicle damage and the occupant injuries in the real-world crash environment across multiple programs. Investigations conducted in NHTSA’s NASS-CDS, SCI and CIREN include:

- A vehicle inspection is conducted that involves detailed documentation including crash deformation, occupant compartment intrusion, occupant contacts, assessment of the safety systems, and photography.
- Additionally, the vehicle inspection includes an image of the Event Data Recorder (EDR) data when available.
- Medical records for injured occupants are evaluated, allowing trained injury coders to assign Abbreviated Injury Scale (AIS) codes and make a determination on the specific
vehicle component that was contacted to produce the injury.

The analysis in this paper is focused on the injury outcomes of the various air bag systems in real world crashes. This was especially important for looking at the injury outcomes that may be related to the advanced air bag occupant protection rulemaking.

BACKGROUND

NHTSA has been collecting in-depth data utilized to study the effects of occupant protection devices since 1972. While the focus of the specific investigations has changed over the years the primary goal has remained to provide researchers the information necessary to protect occupants in crashes with little or no unintended consequences.

The air bag has been utilized as a supplemental form of occupant protection restraint since 1974. Air bag systems have evolved through the years, primarily to mitigate unintended injury consequences to occupants positioned too close to the air bag at the time of deployment. NHTSA initiated interim and long-term regulatory actions to reduce and eventually eliminate the adverse effect of frontal air bags for infants, children, and other high-risk occupants while retaining the benefits of air bags for most people.

These regulatory actions aimed at air bag systems were made based in part on the data collected from NHTSA’s in-depth data collection programs. The data was also utilized to help evaluate the effectiveness of the regulatory actions in real-world crashes [1]. The details on the unintended injury consequences are documented in previous ESV papers [2].

NHTSA’s interim action was to modify the occupant protection Federal Motor Vehicle Safety Standard No. 208 (FMVSS No. 208) to introduce a sled test option in lieu of the existing unbelted barrier crash test certification requirement on March 19, 1997. The sled test allowed air bags to be designed to deploy less forcefully. While some researchers felt this was sufficient, the real-world in-depth data was still reporting unintended consequences. While significantly less than first generation air bags, the undesirable outcome still existed in the sled certified air bags.

In 2000, NHTSA issued another upgrade to FMVSS No. 208 to fulfill its long-term effort to counter the adverse effects of frontal air bags. In this advanced air bag rule, significant changes were specified in the frontal occupant protection requirements for light passenger vehicles. These changes included adding requirements for protecting small adult female occupants, adding requirements to minimize the risk of deploying air bags to out-of-position (OOP) children and small adult occupants, increasing the requirements for belted occupants, and reducing the test speed for the unbelted 50th percentile male occupants. Manufacturers began phasing in the sale of vehicles meeting the advanced air bag requirements beginning with model year 2003 vehicles. All vehicles sold after August 31, 2006 must certify meeting the advanced air bag requirements. Details on the real-world results are included in a previous ESV paper [3].

As of the writing of this paper NHTSA’s crash data systems have not identified or reported any fatality related to the air bag deployment involving a vehicle certified to the advanced air bag requirements.

METHODS

The data used in this analysis were NASS-CDS, SCI, and CIREN cases from crash years 2000-2013 in which a 1990-2013 model year vehicle had a deployed air bag in an occupied seat. The air bags deployment location was not limited to upper instrument panel or steering wheel air bags which were most common. Any deployed air bag location was considered including air bags that deploy from the seat back, roof side rail, door, and mid or lower instrument panel. Especially in more recent model year vehicles, there could be more than one deployed air bag per occupied seating location.

Injuries in NHTSA’s in-depth investigation programs are assigned by trained injury coders based upon the Abbreviated Injury Scale (AIS) developed by the Association for the Advancement of Automotive Medicine (AAAM). Crashes prior to 2010 were coded using AIS90 Update 98. Cases with a crash date 2010 and newer used AIS2005 Update 2008.

NASS-CDS was the primary data analyzed for this paper due to the sheer volume of cases and nationally representative design of the program. In NASS-CDS (2000-2013 in which a 1990-2013 model year vehicle had a deployed air bag in an occupied seat) a total 42,691 deployed air bags fit the criteria as shown in Figure 1. Applying the NASS-CDS weights, these represent over 12.5 million deployed air bags as shown in Figure 2.
From the 42,691 deployed air bags in an occupied seat there were 16,776 instances where an air bag was identified as the source of an injury. These cases represent 4.4 million injuries nationwide during the 14-year period (2000-2013 in which a 1990-2013 model year vehicle had a deployed air bag in an occupied seat) using the weighted data. Though this may seem like a high number of injuries on the surface, Figure 3 shows over 96% of air bag injuries were minor (AIS-1) in severity and likely prevented more severe consequences in most instances. The analysis included all air bag associated injury sources which are listed in Appendix A. It should be noted that NASS and SCI refer to these as injury sources, while CIREN refers to them as involved physical component (IPC).

As the figures 1 and 2 show, the number of injuries attributed to air bags in NASS-CDS has decreased drastically as frontal air bag technology has progressed from first generation, to redesigned, and currently to advanced air bags systems.

Air bags designed to protect occupants in side impacts and rollovers also do not appear to pose a serious threat.

Although there is significant model year overlap in air bag generations due to phase-in periods the Figures 4 and 5 break down vehicle model years into 8-year ranges:

- 1990-1997 (first generation)
- 1998-2005 (redesigned)
- 2006-2013 (advanced)

Figure 4 shows the decrease in the number of total injuries sourced to the air bag in an injury per deployed air bag ratio. The unweighted raw counts as well as weighted values are included.
Figure 4 details vehicles from 1990-1997 averaging just over one coded injury for every two air bags deployed in an occupied seat. More recent air bags from 2006-2013 model year vehicles average less than half as many injuries. The severity of injuries in more recent air bags has also been greatly reduced. Figure 5 shows the decrease in AIS-3 (serious) or greater injuries where air bags were the injury source.

AIS-3+ injuries sourced to the air bag decreased from one in every 101 (.97%) deployed bags in first generation air bags to one in every 2,288 (.04%) deployed air bags in model years 2006-2013, a significant reduction.

Only five AIS-3+ injuries sourced to the air bag have been identified in NASS-CDS in the 2006 and newer model year vehicles. The data are summarized in Table 1. The cases reveal the five injuries involved extremity fractures and there were no indications of air bag malfunction.

Table 1
NASS-CDS cases with AIS-3+ Injury
2006-2013 Model Year Vehicle

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Vehicle</th>
<th>Occupant</th>
<th>Air Bag Location</th>
<th>Injury Code</th>
<th>Injury Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-04-011</td>
<td>2008 Volkswagen Jetta</td>
<td>26-year-old Female Restraint Driver</td>
<td>Steering Wheel</td>
<td>7528043 Radius fracture open/displaced/comminuted</td>
<td>Air bag compartment cover (Probable)</td>
</tr>
<tr>
<td>2008-75-116</td>
<td>2006 Toyota RAV4</td>
<td>90-year-old Female</td>
<td>Top Instrument Panel</td>
<td>7528043 Radius fracture</td>
<td>Air bag (Certain)</td>
</tr>
</tbody>
</table>
SCI
SCI has actively sought out injuries and fatalities associated with air bags since their introduction into the fleet. It is important to remember that SCI cases are not nationally representative and the case selection criteria is very different from NASS-CDS. Table 2 shows the number of AIS-3+ injuries associated with air bags for SCI cases with a crash date 2000-2013. Similar to the NASS-CDS results, the number of AIS-3+ injuries has decreased dramatically in 2006-2013 model year vehicles and no fatalities have been confirmed due to air bag injury sources. Table 3 is a listing of the three AIS-3+ injuries in SCI. There were no indications of air bag malfunction in the cases.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Vehicle</th>
<th>Occupant</th>
<th>Air Bag Location</th>
<th>Injury Code</th>
<th>Injury Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS13002</td>
<td>2012 Hyundai Sante Fe</td>
<td>42-year-old Female Restrained Passenger</td>
<td>Roof Side Rail</td>
<td>6402003 Cord contusion, cervical spine, NFS</td>
<td>Air bag Indirect (Probable)</td>
</tr>
<tr>
<td>DS07009</td>
<td>2006 Cadillac SRX</td>
<td>81-year-old Male Unrestrained Driver</td>
<td>Steering Wheel</td>
<td>4502524 Rib cage fracture open/displaced/comminuted with hemo-/pneumothorax</td>
<td>Air bag (Possible)</td>
</tr>
<tr>
<td>IN11016</td>
<td>2011 Buick Lucerne</td>
<td>78-year-old Female Restrained Driver</td>
<td>Roof Side Rail</td>
<td>6502283 Cervical Spine fracture odontoid (dens)</td>
<td>Air bag (Possible)</td>
</tr>
</tbody>
</table>

Table 2
SCI Air bag sourced AIS-3+ Injuries

<table>
<thead>
<tr>
<th>Model Year Vehicle</th>
<th>AIS-3+ Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1997</td>
<td>328</td>
</tr>
<tr>
<td>1998-2005</td>
<td>91</td>
</tr>
<tr>
<td>2006-2013</td>
<td>3</td>
</tr>
</tbody>
</table>
CIREN
CIREN has six AIS-3+ injuries with an involved physical component (IPC) associated with an air bag in 2006-2013 model year vehicles. CIREN’s ability to identify more air bag injuries than the other in-depth programs is likely due to the programs emphasis on newer model year vehicles, increased medical documentation detail and scrutiny, and biomechanics evaluation. It is important to note that CIREN cases are not nationally representative and the case selection criteria is different from NASS-CDS. Table 4 shows the number of AIS-3+ injuries associated with air bags for CIREN cases with a crash date 2000-2013. Similar to the NASS-CDS and SCI results, the number of AIS-3+ injuries has decreased dramatically in 2006-2013 model year vehicles and no fatalities have been noted due to air bag IPC’s. The six AIS-3+ injuries in SCI are shown in Table 5. There were no indications of air bag malfunction in the cases.

Table 4
CIREN Air bag sourced AIS-3+ Injuries

<table>
<thead>
<tr>
<th>Model Year Vehicle</th>
<th>AIS-3+ Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1997</td>
<td>250</td>
</tr>
<tr>
<td>1998-2005</td>
<td>196</td>
</tr>
<tr>
<td>2006-2013</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 5
CIREN cases with AIS-3+ Injury
2006-2013 Model Year Vehicle

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Vehicle</th>
<th>Occupant</th>
<th>Air Bag Location</th>
<th>Injury Code</th>
<th>Involved Physical Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>857095509</td>
<td>2007 Hyundai Accent</td>
<td>77-year-old Male Restrainted Driver</td>
<td>Steering Wheel</td>
<td>4502303</td>
<td>Rib cage fracture &gt;3 ribs on one side and &lt;=3 ribs on the other side, stable chest or NFS Air bag (Possible)</td>
</tr>
<tr>
<td>857095509</td>
<td>2007 Hyundai Accent</td>
<td>77-year-old Male Restrainted Driver</td>
<td>Steering Wheel</td>
<td>7526043</td>
<td>Humerus fracture open/displaced/comminuted Air bag (Probable)</td>
</tr>
<tr>
<td>842012167</td>
<td>2006 Chrysler PT Cruiser</td>
<td>63-year-old Female Restrainted Driver</td>
<td>Steering Wheel</td>
<td>6502223</td>
<td>Cervical Spine fracture facet Air bag (Probable)</td>
</tr>
<tr>
<td>842012167</td>
<td>2006 Chrysler PT Cruiser</td>
<td>63-year-old Female Restrainted Driver</td>
<td>Steering Wheel</td>
<td>7532043</td>
<td>Ulna fracture open/displaced/comminuted Air bag (Probable)</td>
</tr>
<tr>
<td>842012167</td>
<td>2006 Chrysler PT Cruiser</td>
<td>63-year-old Female Restrainted Driver</td>
<td>Steering Wheel</td>
<td>7528043</td>
<td>Radius fracture open/displaced/comminuted Air bag (Probable)</td>
</tr>
<tr>
<td>100108251</td>
<td>2006 Mercedes E-Class</td>
<td>55-year-old Female Restrainted Driver</td>
<td>Roof Side Rail</td>
<td>1406063</td>
<td>Cerebrum contusion single small Air bag (Probable)</td>
</tr>
</tbody>
</table>
DISCUSSION

The first generation of frontal air bags saved the lives of thousands of drivers and right-front passengers. However, the first generation air bags harmed occupants positioned close to the air bag at the time of deployment, especially small statured females, infants and children. Air bag effectiveness analysis performed by NHTSA’s Office of Regulatory Analysis and Evaluation (ORAE) using Fatality Analysis Reporting System (FARS) and SCI data have shown that as the fleet has moved from first generation to redesigned air bags, the fatality risk was reduced for children and the life-saving benefits of first-generation air bags was preserved for adults [4]. NASS-CDS data in Figures 4 and 5 show the high number of AIS-3+ injuries from air bags decreased over the progression of air bags.

The 2013 ORAE analysis using FARS and R.L. Polk National Vehicle Population Profile (NVPP) data concluded that the progression from redesigned frontal air bags to certified advanced systems showed no statistical significant difference in fatality rate [1]. Recent papers using FARS data through calendar year 2011 show statistically significant fatality reductions for all four types of curtain and side air bags in near-side impacts for drivers and right-front passengers of cars and LTVs [5].

Along with the fatality rate improvement as the fleet has moved from first generation to redesigned and finally to advanced air bags, the reduction in the number of AIS-3+ injuries sourced to the air bag in vehicle model years 2006-2013 has been substantial. These types of injuries have been significantly reduced with only fourteen AIS-3+ air bag injuries identified in all three of NHTSA’s investigation-based programs. These cases were reviewed individually and revealed some common characteristics.

Older occupants were over-represented in the fourteen cases with AIS-3+ injuries sourced to the air bag in vehicle model years 2006-2013 as shown in Figure 6. The average age in the fourteen cases was over 69 years old. NHTSA’s 5-year Traffic Safety Plan for Older People discusses the increased risk that older occupants face, primarily due to increased frailty, and potential measures that could attempt to address injury risks for older occupants [6].

Half the AIS-3+ air bag injuries involved serious lower arm fractures to the radius or ulna. These injuries were identified with high confidence levels for the injury source/inolved physical component. Primarily because of the physical evidence available. Identifying the air bag as the injury source to the other body regions are much more difficult, and often have a confidence level of only “possible.”
common situation is chest injuries to a driver in a severe frontal collision. The driver typically has interaction first with the seat belt, then loads through the air bag into the steering wheel. Determining which of the three components is the source of the specific injury is very challenging and ultimately relies on many factors including: crash scenario, exterior vehicle damage pattern, interior intrusion, occupant contact, interior component deformation, and injury patterns.

**Future Data Collection**

NHTSA currently collects data that can be used to evaluate injury sources in three crash investigation-based programs, NASS-CDS, SCI, and CIREN. In Fiscal Year 2012, Congress appropriated funds for NHTSA to modernize NASS. The formal project, known as the Data Modernization Project, was launched in January 2012. The goal of Data Modernization is to ensure that the agency is collecting quality data to keep pace with emerging technologies and policy needs, which will help affirm NHTSA’s position as the leader in motor vehicle crash data collection and analysis. The multi-year project is set for implementation beginning in January 2016.

The replacement to NASS-CDS has been named the Crash Investigation Sampling System (CISS). New nationally representative data collection sites have been selected using a sample design approach similar to NASS-CDS. The new sites were chosen using the most recent census and vehicle registration data and hope to better reflect the nation’s overall crash picture and improve upon the availability of newer model vehicles and severe crashes at the data collection sites.

NHTSA believes that collection of detailed injury data including medical record collection, AIS code assignment, contacted components, and injury causation must be a point of emphasis in CISS, as well as in the other field investigation-based data collection programs. Current plans include adopting the latest version of the Abbreviated Injury Scale (AIS 2015) and using the U.S. Army Research Laboratory (ARL) Visual Anatomical Injury Descriptor (VisualAID) software to enhance injury coding in all the NHTSA programs.

**CONCLUSION**

Unintended fatalities and serious injuries were a problem in barrier certified (a.k.a. first generation) air bags and to a lesser extent in sled certified (a.k.a. redesigned) air bags. No fatalities in a 2006-2013 model year vehicle have been reported in NHTSA’s investigation-based data collection programs with an air bag attributed as injury source/involved physical component vehicle. The prevalence of AIS-3+ injuries has also been drastically reduced with the introduction of vehicles into the fleet that meet the advanced occupant protection rulemaking. NHTSA’s future data collection efforts will continue to monitor for these types of injuries.
REFERENCES


APPENDIX A

Air bag injury sources 2002-forward
Air bag
Air bag and eyewear
Air bag and jewelry
Air bag and object held
Air bag and object in mouth
Air bag compartment cover
Air bag compartment cover and eyewear
Air bag compartment cover and jewelry
Air bag compartment cover and object held
Air bag compartment cover and object in mouth

NOTE: Beginning in 2002 air bag injuries were linked to a specific air bag

Air bag injury sources 2000-2001
Air bag-driver side
Air bag-driver side and eyewear
Air bag-driver side and jewelry
Air bag-driver side and object held
Air bag-driver side and object in mouth
Air bag compartment cover-driver side
Air bag compartment cover-driver side and eyewear
Air bag compartment cover-driver side and jewelry
Air bag compartment cover-driver side and object held
Air bag compartment cover-driver side and object in mouth
Air bag-passenger side
Air bag-passenger side and eyewear
Air bag-passenger side and jewelry
Air bag-passenger side and object held
Air bag-passenger side and object in mouth
Air bag compartment cover-passenger side
Air bag compartment cover-passenger side and eyewear
Air bag compartment cover-passenger side and jewelry
Air bag compartment cover-passenger side and object held
Air bag compartment cover-passenger side and object in mouth
Other air bag (specify)
Other air bag compartment cover (specify)