CHANGES IN INJURY PATTERNS IN FRONTAL CRASHES: PRELIMINARY COMPARISONS OF DRIVERS OF VEHICLES MODEL YEARS 1993-1997 TO DRIVERS OF VEHICLES 1998-2001.

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ABSTRACT

Injury severity among drivers of vehicles model year 1993-1997 was compared to that of drivers of vehicles 1998-2001. Data from the National Automotive Sampling System Crashworthiness Data Sets 1993-2000 were used. Differences in injury patterns by model year and gender, type of vehicle, single- or multiple-car crash, severity of crash, safety belt use and airbag deployment were investigated. The 1,206 eligible drivers in newer vehicles presented significantly fewer and less severe injuries than their 3,827 pre-1998 model year counterparts. This is true for men and women, across severity of crash, and even when confounders are accounted for. The re-design of frontal airbags that occurred around 1998 could be partly responsible for these improvements.

Motor vehicle crashes remain one of the leading causes of mortality, morbidity and disability for the US population. In 2000, crashes killed 41,821 individuals and injured more than 3 million (NHTSA, 2002). Drivers continue to represent the single largest group of such victims (65%) and approximately 90% of them crash while driving passenger cars, light trucks or minivans (NHTSA, 2002).

Despite the introduction of numerous safety devices over the past decade, the total number of victims, the numbers of victims per 100,000 population, and the number of victims per 10,000 licensed

46th ANNUAL PROCEEDINGS
ASSOCIATION FOR THE ADVANCEMENT OF AUTOMOTIVE MEDICINE
September 30 - October 2, 2002

. Segui-Gómez M, Baker SP. Changes in Injury Patterns in Frontal Crashes: Preliminary Comparison of Drivers of Model Years 1993-1997 and Drivers of vehicles 1998-2001. *Ann Proc Assoc Adv Autom Med* 2002;46:1-14. PMID 12361496.

drivers have remained rather stable since the mid-1990s. Even the number of fatalities and non-fatal injuries per mile driven, which had declined over the past decades, seems to have plateau (NHTSA, 2002; Hilton and Shankar, 2002).

One of the most controversial safety devices introduced during the past years was the frontal airbag (Dalmotas et al, 1996; Frame & MacPherson, 1998). Even prior to their implementation, airbags were the subject of numerous efficacy studies, and upon their introduction in the fleet, many more evaluations were undertaken to determine their effectiveness and efficiency. A very comprehensive review of all those studies and their findings is provided in Kent and Crandall (forthcoming). Briefly, most of those studies found that airbags were associated with an overall protective effect on the drivers. However, those studies also found that among particular groups of drivers (e.g., women, short-stature individuals) or in particular circumstances (e.g., low severity crashes), airbag deployment could have some negative impacts, ranging from inducement of minor injuries to death (NHTSA, 1999; Segui-Gomez, 2000).

As these problems were identified, numerous modifications to the airbag systems were proposed, such as depowering, dual-stage inflators, and raising the deployment thresholds. In addition, new regulatory statutes were introduced to allow for some of those modifications (NHTSA, 2000). Although the specific modifications to the systems probably vary by vehicle maker, model and year, there is some consensus that 1998 represents the first model year (MY) in which modifications were introduced in the fleet (Blue Ribbon Panel, personal communication).

Although it is still early to properly evaluate the effectiveness of these revised airbag systems, there have been already some evaluations confirming the almost complete elimination of airbag-induced deaths among drivers in more modern vehicles (Chidester & Roston, 2001).

The goal of this paper is to evaluate whether there have been any detectable changes in the severity of injuries to drivers of vehicles model year 1998 and more recent in frontal crashes and whether those changes (if any) relate to differences in driver, vehicle or crash characteristics, including airbag deployment.

METHODS

A cross-sectional study design was used to investigate the incidence and severity of injuries among drivers of passenger cars, sport utility vehicles, light trucks or minivans equipped with frontal airbags and involved in frontal crashes. The distributions of those injuries by vehicle model year (MY) were compared after grouping vehicles model year 1993 through 1997 in one category (herein refer to as the pre-1998 vehicles) and vehicles model year 1998 and more recent in another category. Whether those differences in incidence and injury severity by model year related to changes in the distributions of gender or age of the drivers, their use of safety belts, the type of vehicle (passenger car, SUV, light truck or minivan), the actual deployment of the airbag, the type of crash (e.g., single car vs. multiple cars), or its severity (defined by the longitudinal Delta V) was also investigated. More specifically, and for most of the comparisons, the Maximum Abbreviated Injury Severity Score (MAXAIS) (AAAM, 1990) was used as the indicator of severity of injury. All crash-related fatalities were re-coded as MAXAIS=6 so as to not underestimate the severity of those killed in the crash. In several analyses, the proportion of drivers with MAXAIS2+ or MAXAIS 3+ or the body region of the most severe injury were used as dependent variables. When two or more injured body regions had the same level of severity, the priority criteria used was that of the AIS dictionary: Head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, and external (AAAM, 1990).

In order to categorize the severity of the crashes, and in the absence of a standard categorization, the following (previously published) levels were used: longitudinal Delta V of less than 24 km/h, between 24 and <32 Km/h, between 32 and <40 km/h, and 40 km/h or higher (Segui-Gomez, 2000).

Direction of crash was categorized into frontal, including near frontal, crashes (defined in the 10-2 o'clock range) and non-frontal crashes. The 10-2 o'clock criterion was used so that findings could be compared to other existing valuations (Lund & Ferguson, 1995; Kahane, 1996).

To compare the statistical significance of differences in proportions, we used the Chi-square statistic. Statistical significance was defined at the $p<=0.05$ level. Analyses were done using STATA (StataCorp, 1999).

DATA SOURCES & CASE INCLUSION CRITERIA.

National Automotive Sampling System Crashworthiness Data System (NASS CDS) years 1993-2000. Inclusion criteria included being the driver of a passenger car, SUV, light truck or minivan model years 1993-2001, equipped with front driver-side airbags and involved in a frontal or near frontal crashes for which the longitudinal Delta V was known. Also, the driver had to be 16 years

old or older at the time of the crash. Drivers whose death was ruled as due to disease were excluded from the analyses.

RESULTS

The inclusion criteria led to a sample for analysis of 5,033 drivers out of the 50,757 reported in NASS CDS 1993-2000. Table 1 presents the distribution of these drivers, their vehicles, crashes and injuries. Among the 5,033 drivers, 76.0% were in vehicles model year 1993-1997. There are statistically significant differences in injury severity as indicated by their MAXAIS. Drivers in model year 1998-2001 are more likely to sustain no injuries than drivers in older vehicles (30.0% vs. 25.3%, respectively). Also, drivers in more modern vehicles are less likely to sustain injuries to the extremities than drivers in older vehicles, although these differences are only borderline significant.

Besides the injury and body region differences, drivers in model years 1998-2001 are also statistically significantly less likely than drivers in older model years to drive passenger cars, be involved in multiple vehicle crashes, and have their airbag deploy during the crash (Table 1). There seem to be no differences between the two groups with regard to the gender and age composition of the drivers, their use of safety belts or the severity of the crashes that they are involved in.

Whether these differences in injury severity were true for both male and female drivers and across severity of crashes was also investigated. Both male and female drivers in model years 1998-2001 were less likely to sustain MAXAIS 2+ across all Delta V categories. Several of these differences reached statistical significance (Figure 1).

Whether there were any differences in the body region most severely injured by model year and gender was also investigated. Driving more modern vehicles did not result in significant changes in the distribution of the most severely injured body region for neither male nor female drivers. Interestingly, among male drivers whose most severely injured body region were the upper extremities, drivers of more modern vehicles sustained fewer MAXAIS2+ injuries than drivers of older vehicles (10.4% vs 18.8%, respectively. This was also found among female drivers, although the differences in the proportion of MAXAIS2+ if their most severely injured body region was the upper extremity was only borderline significant (17.4% of those driving more modern vehicles vs. 25.4% among those driving older vehicles, p=0.9). Among female drivers whose most severe injury were injuries to the lower extremity, occupants of newer vehicles were statistically significantly less likely to sustain MAXAIS2+ injuries than those in older vehicles (20.1% vs. 28.5%, respectively) (Table 2).

The impact of using a 3-point safety belt was also investigated. Even though there were some differences in the frequency of the most severely injured body regions among belted drivers by model year, none of those differences reached statistical significance. For example, 7.1% of belted drivers in newer vehicles had as their most severe injury a head injury as compared to 4.8% of drivers in older vehicles. In contrast, 26.1% of belted drivers in newer vehicles present their most severe injuries to the upper extremities, as compared to 31.0% of drivers in older vehicles. Unbelted drivers did not have significantly different patters of injuries by model year, neither. For example, 14.4% of unbelted drivers in more modern vehicles had a head injury as their most severe injury, as compared to 14.6% of the unbelted drivers in older vehicles.

The proportion of drivers sustaining MAXAIS2+ by model year was different by vehicle type. As seen in Figure 2, drivers of passenger car model years 1998-2001 are the only drivers for whose reduction in injury severity is statistically significant (from 20.3% to 15.3%). This reduction was also significant when the proportion of MAXAIS3+ was evaluated. Drivers in passenger cars also had a statistically significant reduction, from 25.5% when in model year 1993-1997 to 9.5% when in passenger car model years 1998-2001 (graph not shown).

Since drivers in model years 1998-2001 were involved in fewer multiple-vehicle crashes than drivers in older vehicles (Table 1), injury severity by type of crash was also looked into. Drivers in multiple-vehicle crashes while driving a more recent vehicle were less likely than drivers in older vehicles to sustain MAXAIS2+, particularly among crashes with Delta Vs of less than 40km/h (Figure 3). Drivers of newer vehicles in single crashes were also less likely to sustain MAXAIS2+ injuries in the less severe crashes, although these differences did not reach statistical significance.

The proportion of front driver-side airbags deploying during the crashes were always lower, and almost always statistically significantly lower, among newer vehicles than among older vehicles, even when controlling for the severity of the crash (Figure 4).

Because of this difference in airbag deployment rate, the distributions of MAXAIS by model year and airbag deployment were evaluated. As seen in Table 3, there seems to be a trend towards fewer and less severe injuries in drivers of more modern vehicles across severity of crash. However, with one exception, none of these differences reached statistical significance. The only statistically significant finding relates to the fact that drivers in vehicles model years 1998-2001 in crashes with longitudinal Delta Vs lower than 25 km/h and in which the airbag deployed are significantly more likely not to sustain injuries than drivers in similar crashes but who drove vehicles model years pre-1998 (25.9% vs. 21.1%, respectively). (Interestingly, even drivers in more recent vehicles and in less severe crashes whose airbag did not deploy were more likely not to have injuries than their counterparts in older vehicles (48.5% vs. 43.3%), although this did not reach statistical significance. Regardless of the model year of the vehicle, there were very few cases of airbag-equipped vehicles with no airbag deployment in the more severe crashes, as reflected in several cells in Table 3 with no cases.

DISCUSSION

Drivers in frontal and near frontal crashes of known severity while driving vehicles of model years 1998-2001 seem to sustain significantly fewer and less severe injuries than drivers in similar crashes in airbag-equipped pre-1998 model year vehicles. This is true for all drivers, men, and women, MAXAIS2+, MAXAIS 3+, across crash severity and regardless of whether one measures airbag equipment or airbag deployment. Drivers of these newer vehicles are also more likely to be in vehicles other than passenger cars and be involved in single-vehicle crashes, whereas they are less likely to have their front driver-side airbag deploy during the crash. Yet, the identified differences in injury severity held true even when differences in vehicle type, type of crash ,or airbag deployment were accounted for in the analysis.

Interestingly, we could not identify differences between drivers of newer and older vehicles with respect to their age, gender, use of safety belt, or severity of crash.

The reduction in injuries among drivers of newer vehicles seems to be related to a reduction in the number and severity of upper and lower extremity injuries. However, when more specific analyses of body region and injury severity level were attempted, the limited number of cases available for analyses may have tempered the identification of statistically significant findings.

LIMITATIONS OF THE STUDY. The study's conclusions are limited to drivers of front driver-side airbag-equipped vehicles manufactured after 1993 that are involved in frontal or near frontal crashes for which the severity is known. Information on severity of the crash was missing for about one-third of the otherwise eligible drivers, although there was no differential missing rate between more modern vehicles and their older counterparts (33.7% and 32.2% respectively). The algorithm used by NASS CDS investigators to calculate severity of crash cannot be used if the crash involves rollover, other non-horizontal forces, sideswipe, severe override, or overlapping damage. The algorithm cannot be used neither if data about the crash or vehicle are missing (NHTSA, several years). Whether more modern vehicles are involved at different rates in different types of crashes (e.g., more or less rollover) and whether these other crashes lead to lesser or more serious injuries was not the focus of our investigation.

Another limitation relates to treating all vehicles model years post-1997 as "newer" when normally modifications into the vehicles happen gradually. It is possible that some of the vehicles in our analyses had undergone major changes (including airbag-related changes), whereas others remained practically identical than their older counterparts. We relied on the opinion of experts who concurred that model year 1998 represents the best "cut off" point for the vehicles in the fleet.

Despite these limitations, there seem to be significant reductions in injuries among drivers involved in frontal and near frontal crashes. Whether these changes are due to factors not included in these analyses, such as improved crashworthiness of the vehicles, improved crash identification and medical assistance or others, remains to be investigated.

It is interesting to note that even among less severe crashes in which there was no airbag deployment, drivers in newer vehicles seem to do better than drivers in older vehicles, a finding which seems to speak for these other possible improvements. Airbag system modifications could be partially responsible for the observed injury severity reduction among drivers in newer vehicles. The finding that many fewer airbags are deploying, particularly in less severe crashes, reinforces this hypothesis. Also the fact that, even when airbags deploy drivers sustain less severe injuries suggests changes above modifications of deployment thresholds.

As stated before, it is still early to properly evaluate the effectiveness of the revised driver-side frontal airbag systems.

Nevertheless, the findings reported here offer some insight into the direction of these effects and suggests areas deserving of further analysis when more data on crashes of vehicles model year 1998 or more recent become available.

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