The Impact of Airbags and Seat Belts on the Incidence and Severity of Maxillofacial Injuries in Automobile Accidents in New York State

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Objective: To evaluate the effect driver-side and passenger-side airbags have had on the incidence and severity of maxillofacial trauma in victims of automobile accidents.

Design: Retrospective analysis of all automobile (passenger cars and light trucks) accidents reported in 1994.

Setting: New York State.

Patients: Of the 595910 individuals involved in motor vehicle accidents in New York in 1994, 377054 individuals were initially selected from accidents involving cars and light trucks. Of this subset, 164238 drivers and 62755 right front passengers were selected for analysis.

Main Outcome Measures: Each case is described in a single record with approximately 100 variables describing the accident, eg, vehicle, safety equipment installed and utilized or deployed, occupant position, patient demographics, International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnoses, and procedural treatments rendered. A maxillofacial trauma severity scale was devised, based on the ICD-9-CM diagnoses.

Results: Individuals using airbags and seat belts sustained facial injuries at a rate of 1 in 449, compared with a rate of 1 in 40 for individuals who did not use seat belts or airbags (P < .001). Those using airbags alone sustained facial injuries at the intermediate rate of 1 in 148, and victims using seat belts without airbags demonstrated an injury rate of 1 in 217 (P < .001).

Conclusion: Use of driver-side airbags, when combined with use of seat belts, has resulted in a decrease in the incidence and severity of maxillofacial trauma.


IT IS NOT SURPRISING that motor vehicle accidents continue to plague our nation. National crash statistics of 1997 reveal the alarming figures of nearly 42,000 mortalities, 3.4 million people injured, and an annual cost to the nation of $150.5 billion.1 Based on these findings, several national programs have been initiated to promote safety awareness and injury prevention. Most notable have been campaigns describing the benefits of safety restraints and airbags.

While airbags have received much attention over the past few years, the technology dates back to the early 1970s,2 and although vehicle manufacturers first installed airbags in 1986, it was not until fall 1993 that manufacturers were required to install automatic protection for the driver and right front passenger in all vehicles. Today, over 76 million (39%) of the 200 million cars and light trucks in America have driver-side airbags.3 An additional 1 million new vehicles with airbag systems are sold each month.3 The benefit of airbags in the reduction of driver fatalities is well recognized.4 The National Highway Traffic Safety Administration estimates that over 3448 people (965 belted, 2483 unbelted) are alive today because of their airbags. Additionally, the combination of seat belts and airbags is 75% effective in preventing serious head injuries.1 Recently, however, the airbag’s reputation has shifted from that of a presumed panacea to that of a potentially deadly device. Many case reports have been cited describing injuries resulting from mere airbag deployment. In one case, a fully restrained 24-year-old driver struck a concrete wall while parking her vehicle at low speed (<10 km/h).5 While the damage to the car only involved surface irregularities to the bumper, the deployment of the airbag from the impact resulted in facial abrasions and contusions.

Other, more significant airbag-related injuries have been described, including periobital fracture, superficial...
METHODS

Approval to compile, collect, and maintain the data files required for the study was obtained from the institutional review board of the Albany Medical Center Hospital (Albany, NY); several of the files contained personal identifiers.

Part 1 of the study entailed the review of New York State Department of Health Statewide Planning and Research Cooperative System Hospitalization data from 1990 to 1996. Specifically, all maxillofacial injuries were tabulated, and those injuries resulting from motor vehicle accidents were selected based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Supplementary Classification of External Cause of Injury c-codes. This data set contained the ICD-9-CM diagnoses recorded. Relevant diagnosis codes reflecting maxillofacial injuries were chosen, and frequency tabulations were compared in a time series. This file provides important perspectives on the possible impact of changes in restraints (e.g., mandatory seat belts), and traffic laws (e.g., speed limits). Variables of concern included number of vehicles on the road, population, and motor vehicular fatalities.

Part 2 of the study included an epidemiological analysis of all automobile (passenger cars and light trucks) accidents occurring in 1994 in New York State. All other vehicles were excluded, as current restraint laws and airbag installation requirements apply only to passenger cars and light trucks. The data were derived from the Crash Outcome Data Evaluation System (CODES) project of 1994. The CODES project consists of linked statewide crash and injury data that match vehicle, crash, and human behavior characteristics to their specific medical and financial outcomes. The sources for these data include police accident reports, emergency medical service response data (including prehospital care reports), and hospital admission data (ICD-9-CM codes for diagnoses and procedures performed, represented by the SPARCS data set). The CODES project represents standardized, validated, linked data. Linkage allows individuals involved in the automobile accident to be traced from the scene to their final medical outcomes. Data from the police accident reports were reviewed to identify drivers and right front seat passengers involved in automobile accidents, preliminary injury status, and safety equipment status (equipment installed and/or used). Occupants were then grouped based on the type of safety mechanism used at the time of accident:

- Group 1: no lap/harness restraint and no airbag (not activated or not present)
- Group 2: no lap/harness restraint and airbag deployed
- Group 3: lap/harness restraint in use and no airbag (not activated or not present)
- Group 4: lap/harness restraint in use and airbag deployed

Each group was reviewed with regard to treatment status (outpatient vs inpatient). This further subdivision was analyzed in terms of extent of maxillofacial injury (none, minor [abrasions, contusions, minor soft tissue trauma]; moderate [lacerations, fractures not requiring open reduction and internal fixation]; or major [maxillofacial trauma requiring open reduction internal fixation]). A list of the ICD-9-CM codes used is available from the authors. Inpatient data were obtained from the New York State Department of Health Information Systems and Health Statistics Group (SPARCS data). Specific inpatient variables collected included permanent facility identifier, hospital county code, age of patient, sex of patient, diagnosis upon admission or principal diagnosis, and all other diagnoses.

In particular, ICD-9-CM codes representing maxillofacial trauma were noted and tabulated. The resulting data set pertains to 377,054 individuals involved in approximately 209,500 motor vehicle accidents. These data were obtained from common passenger vehicles, including automobiles, vans, minivans, pickup trucks, and utility vehicles. Each case was described in a single record with approximately 100 different variables describing the accident, the vehicle, description of the accident, the injured victim, the hospital diagnoses, and the hospital treatments. From this group, drivers and right front passengers were identified and analyzed.

Univariate and bivariate data analysis was performed. Pearson χ² analysis was used to determine significance of the observed differences and to examine the effect of airbags and seat belts on maxillofacial injuries. Logistic regression was used to calculate odds ratios. All statistical analyses were performed using SPSS 8.0 and SPSS 9.0 software for Windows (SPSS Inc, Chicago, Ill).

burns, severe head injuries, and otologic injuries ranging from temporary threshold shifts to persistent tinnitus and dys equilibrium. Airbag-associated deaths have prompted a vigorous public education campaign to prevent these avoidable injuries. As of September 1, 1998, 113 deaths (15 children in rear-facing child safety seats, 51 children improperly restrained, 42 adult drivers [11 properly restrained], and 3 adult passengers [2 restrained]) were attributed to airbag deployment. In response, the National Highway Traffic Safety Administration has taken measures to preserve the benefits of airbags while reducing their risks, such as issuing mandatory warning labels on new vehicles and child safety seats (as of November 1996), allowing automobile manufacturers to install off-switches (ie, directly linked to the airbag), and promoting further testing and consideration of advanced or depowered airbag technology. In fact, advanced air bags, which possess the ability to sense the position of the occupant and the restraint status, will be required in all new cars and light trucks as of September 1, 2005.

In view of this recent critique of airbags, we reviewed general surgical trends across New York State over the past decade. A survey of chairpersons of otolaryngology–head and neck surgery residencies from various regions revealed a perceived decline in the incidence of automobile accident–related maxillofacial trauma necessitating surgical treatment.

To date, no study has analyzed the effect of airbags on the incidence and severity of maxillofacial trauma.
The goal of this study is to provide an epidemiological analysis to further our understanding of the impact airbags have had on the surgical treatment of maxillofacial trauma. More specifically, the study is an effort to quantify the impact of airbags on the incidence and severity of maxillofacial injuries to occupants of passenger vehicles.

RESULTS

HOSPITAL ADMISSIONS FROM 1990 TO 1996

The total of all maxillofacial fractures (ICD-9-CM diagnosis code 802) resulting from motor vehicle accidents from 1990 through 1996. The average age of the accident victims was 38 years. Men accounted for 63.2% of the automobile accident victims.

Table 1 shows New York State epidemiological data collected from 1988 through 1997 and maxillofacial trauma data collected between 1990 and 1996.

The following is a timeline of important events:

- December 1, 1984: Seat belts are required for occupants of all passenger cars and light trucks, in all front seat positions.
- 1986: Airbags are introduced to the United States by Mercedes-Benz.
- August 1995: Speed limits are raised to 65 mph on specific sections of rural interstate highways. Speed limits in these areas had been set at 55 mph in 1974 as a response to the oil crisis.

These data do not contain information on the type of motor vehicle accident or safety equipment installed or used by the victims. Analysis of the data demonstrates a decreasing trend of fractures related to motor vehicular accidents. During this period, the population and vehicle registration counts remained stable.

1994 CODES PROJECT CRASH RECORDS

The total number of police reports on individuals involved in motor vehicle accidents in 1994 was 395900. Of these, 377,054 cases that involved cars, light trucks, vans, minivans, and sports utility vehicles were selected. From this total, only drivers (n=240,091 [63.7%]) and right front occupants (n=69,843 [18.5%]) were selected for analysis. Ultimately, definitive identification of safety equipment status reduced the number of cases to 226,993 cases (164,238 drivers and 62,755 passengers), 55.4% male and 44.6% female. Friday was the day with the highest frequency of accidents (16.7%).

Further analysis of the right front occupants revealed that only 2,374 cases involved the use of airbags, reflecting the small number of vehicles possessing passenger-side airbags in 1994. While descriptive, these data were abandoned because of the lack of power when comparing this small subgroup with the right front occupants of vehicles without airbags (>60,000 cases). All subsequent analysis was directed at the driver position.

Table 2 gives the demographic profiles of the drivers with and without airbags.

Table 3 describes all maxillofacial injuries, subdivided by severity score and by presence or absence of airbags. Although the overall number of facial injuries

<table>
<thead>
<tr>
<th>Year</th>
<th>State Population†</th>
<th>Motor Vehicles Registered†</th>
<th>Motor Vehicle Accidents (MVA)†</th>
<th>Motor Vehicle Fatalities†</th>
<th>MVA-Related Maxillofacial Trauma‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>17,923,638</td>
<td>10,507,196</td>
<td>312,765</td>
<td>2,237</td>
<td>NA</td>
</tr>
<tr>
<td>1989</td>
<td>17,973,344</td>
<td>10,634,771</td>
<td>321,696</td>
<td>2,263</td>
<td>NA</td>
</tr>
<tr>
<td>1990</td>
<td>17,990,455</td>
<td>10,780,683</td>
<td>308,107</td>
<td>2,211</td>
<td>1576</td>
</tr>
<tr>
<td>1991</td>
<td>18,031,466</td>
<td>10,364,308</td>
<td>274,875</td>
<td>1,988</td>
<td>1592</td>
</tr>
<tr>
<td>1992</td>
<td>18,071,135</td>
<td>9,987,697</td>
<td>258,596</td>
<td>1,808</td>
<td>1571</td>
</tr>
<tr>
<td>1993</td>
<td>18,110,891</td>
<td>9,109,590</td>
<td>257,299</td>
<td>1,774</td>
<td>1509</td>
</tr>
<tr>
<td>1994</td>
<td>18,169,051</td>
<td>9,149,276</td>
<td>259,184</td>
<td>1,669</td>
<td>1191</td>
</tr>
<tr>
<td>1995</td>
<td>18,136,081</td>
<td>9,176,688</td>
<td>253,136</td>
<td>1,670</td>
<td>1206</td>
</tr>
<tr>
<td>1996</td>
<td>18,184,774</td>
<td>9,235,437</td>
<td>250,521</td>
<td>1,590</td>
<td>1118</td>
</tr>
<tr>
<td>1997</td>
<td>18,137,226</td>
<td>10,027,422</td>
<td>263,604</td>
<td>1,630</td>
<td>NA</td>
</tr>
</tbody>
</table>

*NA indicates data not available.
†Data from the New York State Department of Motor Vehicles.
‡New York State Department of Health Statewide Planning and Research Cooperative System data.

Table 2. Descriptive Statistics for Drivers

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Airbag (n = 39,097)</th>
<th>No Airbag (n = 125,141)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female, %</td>
<td>55.5/44.5</td>
<td>59.2/40.8</td>
</tr>
<tr>
<td>Seat belt used, %</td>
<td>84.0</td>
<td>92.0</td>
</tr>
<tr>
<td>Mean age, y</td>
<td>41.5</td>
<td>38.3</td>
</tr>
</tbody>
</table>

Table 3. Number and Severity of Maxillofacial Injuries

<table>
<thead>
<tr>
<th>No. (%)</th>
<th>Airbag (n = 39,097)</th>
<th>No Airbag (n = 125,141)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All maxillofacial injuries</td>
<td>115 (0.3)</td>
<td>769 (0.6)</td>
</tr>
<tr>
<td>Minor</td>
<td>101 (87.8)</td>
<td>634 (82.4)</td>
</tr>
<tr>
<td>Moderate</td>
<td>6 (5.2)</td>
<td>80 (10.4)</td>
</tr>
<tr>
<td>Major</td>
<td>8 (7.0)</td>
<td>55 (7.2)</td>
</tr>
</tbody>
</table>

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is small (approximately 900), it is comparable to the longitudinal data set (Table 1) (1191 cases of motor vehicle accident–related maxillofacial trauma recorded in 1994).

Table 4 shows a cross-tabulation of seat belt use by facial injury controlling for airbag installation in the vehicle. Drivers using airbags in combination with seat belts had a significant decrease in the incidence and severity of facial injuries (rate of injury, 1 in 449) compared with individuals using only seat belts (rate of injury, 1 in 217), airbags alone (rate of injury, 1 in 148), or no restraint (rate of injury, 1 in 40) (P < .001 by Pearson χ² analysis for all comparisons).

Table 5 depicts the incidence of facial trauma as an odds ratio (the dependent variable is severe facial injury requiring hospital admission; independent variable is airbag present or seat belt used). Drivers of vehicles with airbags were 58% less likely to sustain a severe facial injury requiring hospital admission (compared with drivers of vehicles without airbags). Drivers who wore seat belts were 77% less likely to sustain a severe facial injury requiring hospital admission (compared with drivers who did not wear seat belts).

The challenges of performing an epidemiological study of automobile-related maxillofacial trauma are readily apparent. In order to demonstrate causality, it is paramount to isolate variables that are pertinent to the analysis. Clearly, the longitudinal study between 1990 and 1996 helps to illustrate general trends in incidence and severity. Overall, there has been a gradual decrease in the incidence and severity of facial injuries resulting from automobile crashes. Several factors may have contributed to this trend. The increasing use of restraint systems, safety legislation, and public awareness have all had a perceived positive effect on morbidity and mortality related to motor vehicle accidents. However, the ever-increasing reports of airbag-related injuries prompted our investigation.

It was evident that determining the cause-and-effect relationships associated with airbag-associated vehicular crashes required a sophisticated compilation of data. In order to establish causality, linkage of data sources is required. The New York State CODES project of 1994 represents linked data that follow individuals from the scene of the accident to their final medical outcome. More important, these data represent a comprehensive and well-documented source of information not collected elsewhere. Unique to this data set is the ability to determine the features of the crash (eg, the location, objects hit, weather conditions), vehicular information (including safety restraints used and installed), and hospitalization data (ICD-9-CM diagnoses and procedures). Our analysis of these data revealed a significant difference in the outcome of maxillofacial trauma comparing individuals who used airbags and restraints with those who did not use safety equipment. Specifically, drivers using airbags in combination with seat belts were found to have a significantly lower incidence and severity of facial injuries (rate of injury, 1 in 449) compared with individuals using only seat belts (rate of injury, 1 in 217), airbags alone (rate of injury, 1 in 148), or no restraint (rate of injury, 1 in 40) (P < .001 for all comparisons).

Nevertheless, there are limitations and biases in this investigation. First, data reporting depends upon a human element. For example, accident reports rely on self-reporting of safety restraint usage. Clearly, with the current safety laws, seat belt usage data may be artifactually elevated. Additionally, accuracy of diagnostic and procedural codes may be influenced by anticipated financial reimbursement.

One of the more difficult aspects of this analysis has been the need to compare similar accidents. There may have been an inherent bias toward severe automobile crashes associated with airbag deployment. In fact, airbags were first introduced in more expensive, high-performance (sports) vehicles, which are designed to be driven differently than, for example, family vehicles. More important, airbags are designed to deploy in frontal impacts. It is recognized that head-on collisions result in 3 times the fatality rate and twice the injury rate of other types of collisions. Therefore, the data recorded may reflect the most severe accidents associated with airbag deployment. In essence, airbag deployment is an indicator of accident severity.

A prospective study over a longer time (ie, several years) would provide a larger study sample, especially given the limited number of documented facial injuries encountered in the 1994 data (<2000); this would permit the analysis of a greater number of crashes involving airbags, as the number of vehicles with airbags continues to increase. Future investigations should also consider accident details as predictors of accident severity (eg, road and weather conditions, weights of vehicles).
One variable that is missing from our data set is velocity. Although velocity is an important factor in determining the severity of an accident, these data are not included in police accident reports.

Public response to issues such as the adverse effects of airbags has been the impetus behind changes in safety measures. Manufacturers are continuing their efforts to depower airbags and provide deactivated technology. However, an epidemiological review of injuries related to automobile accidents helps differentiate causation from anecdotal case reports. In this study, airbags used in conjunction with seat belts resulted in the least severe maxillofacial injuries. This supports the current recommendation by the National Highway Traffic Safety Administration that airbags should be used as an adjunct to seat belt restraint systems and should not be viewed as sole safety devices. It is hoped that investigations such as ours will help provide a basis for future evaluations of public safety policies.

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