

# Facial Fractures in Motor Vehicle Collisions

## Epidemiological Trends and Risk Factors

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**Objectives:** To analyze epidemiological trends in facial fractures sustained in motor vehicle collisions and to identify the effects of occupant and crash-specific characteristics on the likelihood of injury.

**Methods:** A retrospective cohort analysis of vehicle occupants with facial fractures following a motor vehicle crash was performed using the population-based 1993-2005 National Automotive Sampling System Crashworthiness Data System database. Injury trends were analyzed by calendar year and vehicle model year. A multivariate analysis was performed on biomechanical, demographic, and safety restraint data, with the calculation of odds ratios (ORs) and 95% confidence intervals (CIs).

**Results:** The incidence of facial fractures was found to be decreasing ( $P < .01$ ), along with a declining probability of injury with newer car models ( $P < .01$ ). Seat belts

with frontal air bag use were associated with a significantly decreased probability of facial fracture (OR, 0.14; 95% CI, 0.09-0.22). Air bags alone were not associated with a reduced probability of injury (OR, 0.78; 95% CI, 0.58-1.06). Side impacts (OR, 1.81; 95% CI, 1.14-2.86) and mismatch in the sizes of the crash vehicles (OR, 1.99; 95% CI, 1.27-3.12) were associated with increased risk of facial fractures.

**Conclusions:** The probability of facial fractures from motor vehicle collisions is decreasing. This finding may be due to design improvements implicitly related to vehicle model year. Restraint use continues to be important for injury prevention, while factors such as changes in vehicle fleet composition may alter injury trends.

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**F**ACIAL TRAUMA IS THE MOST common injury to occupants involved in motor vehicle collisions (MVCs) and, along with skull base trauma, represents a significant cause of morbidity in all age groups.<sup>1</sup> Furthermore, maxillofacial fractures have been associated with a high incidence of concomitant injuries, including ocular and intracranial injuries.<sup>2</sup> The National Highway Traffic Safety Administration (NHTSA) estimated in 2000 that the unit cost per facial injury in terms of lost productivity, medical costs, legal fees, emergency service, insurance administration costs, travel delay, property damage, and workplace losses ranged between approximately \$9000 and \$725 000 per injury.<sup>3</sup>

Studies to date have focused primarily on the association between maxillofacial injuries and the use of restraint systems. These studies have shown that the use of seat belts along with air bags significantly reduces the risk of maxillofacial injury compared with unrestrained occupants.<sup>4-6</sup> However, occupant factors such

as age, sex, and body habitus, vehicle safety design features, and crash scenario factors such as crash velocity and the types of vehicles involved were not included in these prior analyses,<sup>7-9</sup> and there is little data on the effects of these factors on the risk of skull base injuries.<sup>10</sup>

We hypothesized that the probability of facial and skull base fractures has decreased with changing automotive design and restraint use. Furthermore, we wished to characterize specific occupant and crash-related factors associated with these types of fractures.

## METHODS

### DATA SOURCE

Data for this study were obtained from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) database.<sup>11</sup> This database, maintained by the NHTSA, is a nationally representative probability sample of police-reported tow-away motor vehicle collisions. Because the CDS data set represents a probability sample, each variable

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is weighted to produce national estimate numbers. The CDS collects a sample of approximately 5000 cases annually from 24 to 27 geographic areas selected from a pool of 1195 possible sites. Case files in the CDS database are assembled by crash investigators using police reports and hospital files, as well as physical evidence from the crash scene and vehicles involved. NASS field teams also conduct interviews with crash victims whenever possible. In total, the CDS database uses over 300 variables to describe event sequences, crash physics, and vehicle, occupant, and injury characteristics.

## STUDY POPULATION

The study population consisted of drivers and front seat occupants of passenger cars and light trucks, sports utility vehicles, or vans (LTVs) (<4536-kg gross vehicle weight) involved in frontal and side collisions between 1993 and 2005. Occupants were included if they sustained fractures of the mandible, nose, midface, orbit, frontal sinus, or skull base. Occupants younger than 16 years and those ejected or involved in rollover collisions were excluded to maintain cohort population homogeneity regarding body mass, sitting position, and restraint use<sup>12</sup> and to allow appropriate velocity assessment.

## DATA SELECTION

Injuries were selected from the NASS CDS data, which uses the Abbreviated Injury Scale (1990 revision) developed by the Association for the Advancement of Automotive Medicine.<sup>13</sup> These codes describe the body region injured and the severity of each injury. Injuries selected for analysis were all nasal, maxillofacial, mandible, skull base, and anterior cranial vault fractures, which included frontal sinus fractures. Given the equivocal nature of previously published data on the effects of vehicle and restraint characteristics on these injuries and the clinical relevance of existing categorizations, we arbitrarily subdivided fractures into the following 3 categories: (1) facial fractures, including all mandible, midface, and orbit fractures, (2) skull base and frontal sinus fractures, and (3) nasal fractures, which included both simple and complex or comminuted fractures. The skull base group also included some cranial vault fractures owing to the nature of coding limitations within the Abbreviated Injury Scale (1990 revision) system. Because many occupants had multiple injuries, data for each injury category was pooled separately and analyzed independently. Thus, for example, an occupant who had both a facial fracture and a skull base fracture was included in both the facial fracture population and the skull base fracture population. Occupants who had multiple fractures within a designated injury category were counted only once for that category.

Collision type was defined on the basis of correlation between the identified principal direction of force (PDOF) on the vehicle and the location of maximal damage. With 0° defined as the front of the vehicle and 180° defined as the rear of the vehicle, frontal impacts were defined as having a PDOF between 315° and 45°, with a primary area of damage at the front of the vehicle. Side impacts were defined as having a PDOF between 226° and 314° or between 46° and 134° and a corresponding area of damage corresponding to the left or right side of the vehicle, respectively. This was done to exclude events such as side-swipe collisions, which might have a PDOF from the front or rear but incur damage primarily to the side of the vehicle.

Other collision variables included the net change in velocity due to collision ( $\Delta V$ ), vehicle body type, vehicle body type of any crash partner, and a derived variable describing crash combinations between different crash partners. The crash part-

ner variable has 1 of 5 possibilities: automobile vs automobile, automobile vs LTV, LTV vs automobile, LTV vs LTV, and automobile vs nonautomobile (eg, stationary object). Occupant variables included age, sex, height, weight, role (driver vs passenger), and restraint type. For restraint use, occupants were grouped into the following 4 categories of restraint use: unrestrained, seat belt alone, seat belt with air bag, and air bag alone.

## STATISTICAL ANALYSIS

As a preliminary step, a univariate logistic regression was performed using the SURVEYLOGISTIC procedure in SAS (SAS Institute, Cary, North Carolina) to compare the effects of the variables of interest on each of the 4 outcomes using the sampling design in the CDS data set. In each case, the odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were calculated.

Once a subset of significant variables was identified from the univariate analysis, these items were then subjected to logistic multivariate analysis using PROC SURVEYLOGISTIC in SAS. There was a significant amount of missing data for the  $\Delta V$  variable in the CDS data set, with approximately 40% of values absent. Multiple imputation with 5 replicates based on regression of  $\Delta V$  on age, sex, vehicle body types, air bag deployment, and impact type was used to create values for missing data, based on our variables of interest. The effects of each variable were calculated while adjusting for the effect of all other variables in the analysis. As in the univariate analysis, the same reference groups were used, and odds ratios, *P* values, and confidence intervals were calculated for injury risk.

Finally, trend analysis using survey-adjusted logistic regression was performed to characterize injury probability and incidences for each of the 4 outcome categories both by vehicle model year and calendar year for the study period.

## RESULTS

In the CDS data set, in the United States from 1993 to 2005, a total of 167 391 occupants had 1 or more facial fractures, 55 150 had skull base or frontal sinus fractures, and 196 855 had nasal fractures. All of the occupant, collision, restraint, and vehicle characteristics are listed in **Table 1**. The majority of subjects were male drivers, and most occupants were restrained with either seat belts alone or in combination with air bags for all fracture groups. Other occupant demographic characteristics were similar across fracture categories. The majority of impacts were frontal impacts (60.1% to 81.3%) and the mean  $\Delta V$  ranged from 33.4 to 44.8 km/h. Automobiles represented the majority of vehicles involved in collisions (72.0% to 74.1%) and stationary objects were the most common crash partner (56.1% to 60.1%).

## TREND ANALYSIS

The probability of facial fractures decreased significantly with newer vehicle models ( $P < .001$ ), as shown in **Figure 1A**. This significant trend was also observed for skull base and nasal fractures ( $P < .001$  and  $P < .009$ , respectively), as shown in **Figure 1B** and **C**. In addition, from 1993 to 2005, the per-calendar year probability of facial fractures decreased significantly ( $P < .01$ , **Figure 2A**). The per-calendar year probability of skull base and nasal fractures over the same interval did not

**Table 1. Occupant, Collision, and Vehicle Characteristics**

Occupant Characteristic	Facial Fractures (n=167 391)	Skull Base Fractures (n=55 150)	Nasal Fractures (n=196 855)
Age, mean, y	37.3	33.4	36.4
Height, mean, cm	173.5	174.8	174.5
Weight, mean, kg	74.4	79.5	75.3
BMI, mean	24.7	25.9	24.5
Male, %	80.1	78.1	84.0
Female, %	19.9	21.9	16.0
Driver, %	63.6	61.9	64.5
Passenger, %	36.4	38.1	35.5
Collision characteristics			
Frontal, %	69.5	60.1	81.3
Side, %	21.3	27.7	12.6
Other, %	9.2	12.2	6.1
ΔV, mean, km/h	40.7	44.8	33.4
Restraint use, %			
Air bag	4.6	7.0	6.2
Seat belt	40.8	36.5	41.2
Seat belt and air bag	8.8	21.4	10.8
Unrestrained	45.8	35.0	41.8
Vehicle characteristic, %			
Auto	72.0	74.1	73.8
LTV	28.0	25.9	26.2
Crash partner, %			
Auto	16.2	17.9	20.5
LTV	23.2	26.0	19.4
Auto vs auto	60.6	56.1	60.1

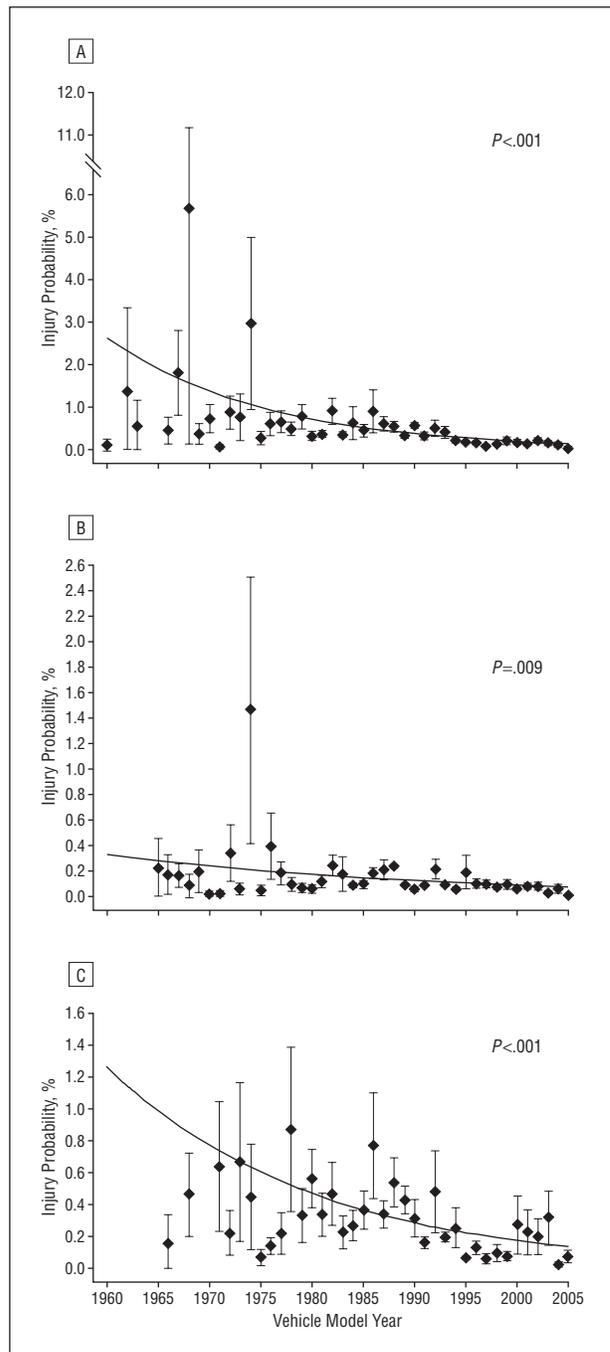
Abbreviations: Auto, automobile; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); LTV, light truck, sports utility vehicle, or van; ΔV, amount of velocity lost by the vehicle due to collision.

demonstrate significant changes over the same interval (Figure 2B and C).

### MULTIVARIATE ANALYSIS

**Table 2** gives the odds ratios and associated 95% confidence intervals for injury probability in the facial fracture group. When adjusted for other characteristics, factors associated with a significantly increased risk of facial fracture were side impact, increasing ΔV, increased occupant height, nonuse of restraints, and collision with an LTV or stationary object, regardless of the occupant's own vehicle class. Occupants who were restrained with seat belts only, as well as those restrained with seat belts and air bags, were significantly less likely to have facial fractures. Air bags alone were not associated with a reduced probability of facial fractures, and there was no difference in injury probability between sexes or based on occupant weight.

The skull base fracture group (**Table 3**) demonstrated a similar trend with the exception that increased occupant height was not associated with a change in probability of injury. Side impacts were strongly associated with skull base fractures. Nasal fractures (**Table 4**) demonstrated a slightly different profile. In contrast to the facial and skull base fracture groups, there was a trend toward increased risk with frontal impacts, although this was not statistically significant. In addition, occupants involved in other types of collisions (eg, rear impacts) were significantly less likely to have nasal fractures. Crash

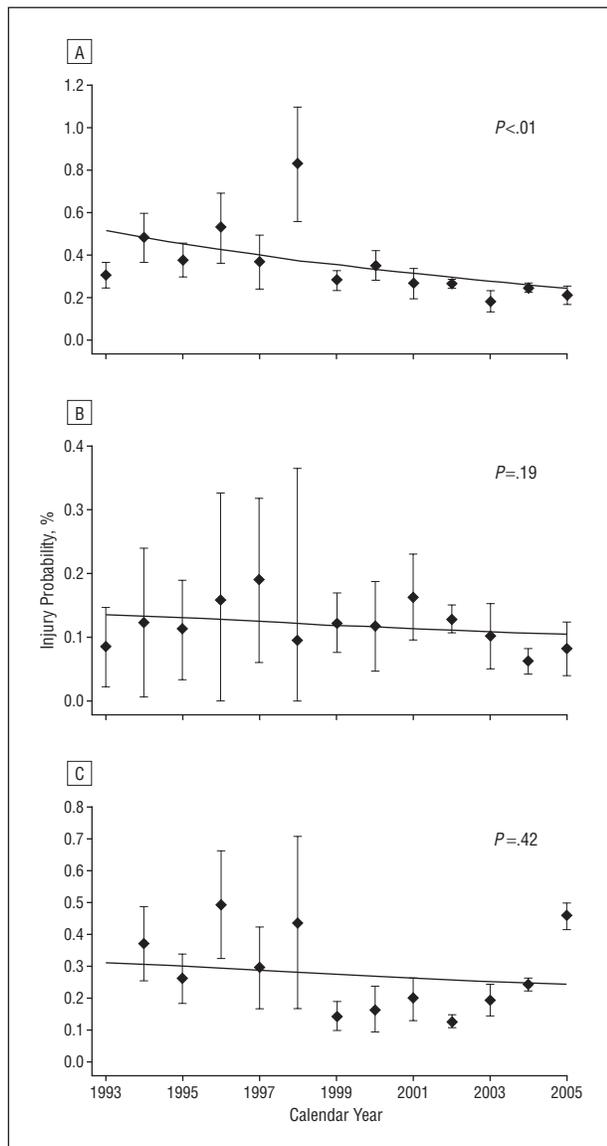


**Figure 1.** The probability of facial (A), skull base (B), and nasal (C) fractures in motor vehicle crashes by vehicle model year. Error bars indicate standard error.

partner alterations did not significantly influence the risk of nasal fracture. Both skull base and nasal fracture groups demonstrated significantly decreased probability of injury in the seat belt and seat belt with air bag restraint groups. Within these groups, air bag use alone was not associated with a decreased probability of injury.

### COMMENT

We sought to characterize changes in fracture probability in 2 ways. First, we performed a calendar year analysis to examine broad epidemiological changes that would



**Figure 2.** The probability of facial (A), skull base (B), and nasal (C) fractures in motor vehicle crashes by calendar year. Error bars indicate standard error.

presumably be affected by factors such as restraint use and availability, changing vehicle safety technology, and automotive fleet demographics. We also examined epidemiologic changes in facial and skull base fractures as a function of vehicle model year as a surrogate to reflect cumulative advances in crashworthiness technology and restraint availability. In this study, we were able to demonstrate a significant trend toward reduction of injury probability across all of our fracture categories with newer car models. To our knowledge, this is the first study to demonstrate an actual reduction in maxillofacial and skull base fracture injury probability related to newer vehicle designs. As older cars are scrapped and more vehicles with next-generation safety features enter the vehicle fleet, we would expect decreasing injury probabilities and ultimately overall decreased injury incidence for year-to-year trends. We were able to demonstrate this trend for our facial fracture group, although our other injury categories did not demonstrate any significant changes.

**Table 2. Facial Fracture Injury Risk Factors<sup>a</sup>**

Factor	OR (95% CI)	P Value
Impact characteristic		
Other	0.66 (0.41-1.07)	.10
Side	1.81 (1.14-2.86)	.01
Frontal	1 [Reference]	
ΔV	1.05 (1.04-1.05)	<.001
Demographic		
Female	0.96 (0.67-1.37)	.82
Male	1 [Reference]	
Height	1.02 (1.00-1.04)	.006
Weight	0.99 (0.98-1.01)	.39
Restraint type		
Air bag	0.78 (0.58-1.06)	.11
Seat belt	0.21 (0.16-0.28)	<.001
Seat belt and air bag	0.14 (0.09-0.22)	<.001
Unrestrained	1 [Reference]	
Crash partner		
Auto vs LTV	1.99 (1.27-3.12)	.003
LTV vs Auto	0.97 (0.78-1.19)	.75
LTV vs LTV	2.07 (1.36-3.15)	<.001
Auto vs non-Auto	3.60 (2.58-5.03)	<.001
Auto vs Auto	1 [Reference]	

Abbreviations: Auto, automobile; CI, confidence interval; LTV, light truck, sports utility vehicle, or van; OR, odds ratio; ΔV, amount of velocity lost by vehicle due to collision.

<sup>a</sup>Adjusted for impact type, sex, height, weight, restraint type, ΔV, and crash type.

**Table 3. Skull Base Injury Risk Factors<sup>a</sup>**

Factor	OR (95% CI)	P Value
Impact characteristic		
Other	1.22 (0.58-2.58)	.60
Side	3.35 (2.17-5.17)	<.001
Frontal	1 [Reference]	
ΔV	1.05 (1.04-1.05)	<.001
Demographic		
Female	0.88 (0.58-1.33)	.55
Male	1 [Reference]	
Height	1.02 (1.00-1.04)	.08
Weight	1.01 (1.00-1.02)	.10
Restraint type		
Air bag	1.24 (0.82-1.87)	.31
Seat belt	0.18 (0.13-0.25)	<.001
Seat belt and air bag	0.24 (0.14-0.39)	<.001
Unrestrained	1 [Reference]	
Crash partner		
Auto vs LTV	3.30 (1.82-5.98)	.003
LTV vs Auto	0.53 (0.27-1.04)	.07
LTV vs LTV	2.66 (1.45-4.88)	.002
Auto vs non-Auto	3.79 (2.61-5.51)	<.001
Auto vs Auto	1 [Reference]	

Abbreviations: Auto, automobile; CI, confidence interval; LTV, light truck, sports utility vehicle, or van; OR, odds ratio; ΔV, amount of velocity lost by vehicle due to collision.

<sup>a</sup>Adjusted for impact type, sex, height, weight, restraint type, ΔV, and crash type.

We were also able to identify several factors that were associated with alterations in the risk for fractures. For collision characteristics, across all fracture categories, increasing ΔV was associated with increased risk of injury. In addition, side impacts were strongly associated

with increasing probability of facial and particularly skull base and frontal sinus fractures. This suggests that side impacts remain an area where current vehicle and restraint technology may be inadequate. One area of promise in this arena has been the advent of side air bags. However, these restraints have only become recently available, and studies to date have not been able to confirm their effectiveness in injury reduction.<sup>14</sup>

With regard to restraint use, our findings match those of other studies<sup>4,5</sup> that have demonstrated the effectiveness of restraint use in preventing facial fractures. Our data also demonstrate restraint effectiveness in the prevention of skull base and frontal sinus fractures. Seat belts remain the most important restraint modality in this regard, and our data likewise support prior work showing that air bags alone do not confer protection advantages.<sup>4</sup> Some authors have proposed that the force of air bag deployment may predispose exposed occupants to increased risk of minor fractures such as nasal fractures<sup>15,16</sup>; however, we did not find any association between air bag deployment and increased risk of fracture. Our results also reflect increasing use of restraint systems among the population, with approximately 50% to 60% of our study population using an effective restraint measure.

Crash partner data demonstrated that the most significant risk for all fracture types was impact with non-automobile, nontruck objects. In our data set, the majority of these impacts were with stationary objects such as trees, telephone poles, or other static structures. In addition, our findings run somewhat counter to conventional wisdom that occupants of larger vehicles such as LTVs necessarily derive protective benefits due to the larger vehicle size. There was no significant protective benefit in cases when occupants riding in LTVs collided with automobiles. Furthermore, there was a significantly increased probability of facial and skull base injury when occupants in LTVs collided with other LTVs. Conversely, however, occupants in automobiles that collided with LTVs were significantly more likely to sustain facial and skull base fractures. This suggests that more LTV-type vehicles entering the fleet contribute a net effect toward increasing the probability of these types of injuries.

We also examined the impact of several occupant factors on the probability of injury. Only increasing height was associated with increased probability of both nasal and facial fractures. Though the magnitude of the increased odds ratio was small, the statistical analysis was based on 1-cm incremental differences in height, implying that if we had compared cohorts of the tallest and shortest occupants, more dramatic odds ratios would have been demonstrated. We were unable to identify a relationship between other factors such as weight and sex with respect to injury probability, and we did not specifically attempt to identify "out of position" occupants. Further crash testing studies may provide a role in identifying relationships between these factors and injury mechanisms.

There are several limitations to this study. First, it must be recognized that the CDS data does not represent a true national incidence owing to case selection bias, which tends to favor more severe crashes. It is probable that many collisions that result in facial injury, especially minor fractures such as nasal fractures, would not be included in

**Table 4. Nasal Fracture Injury Risk Factors<sup>a</sup>**

Factor	OR (95% CI)	P Value
Impact characteristic		
Other	0.40 (0.21-0.75)	.005
Side	0.82 (0.53-1.26)	.36
Frontal	1 [Reference]	
ΔV	1.03 (1.03-1.04)	<.001
Demographic		
Female	0.81 (0.55-1.22)	.32
Male	1 [Reference]	
Height	1.03 (1.01-1.04)	<.001
Weight	0.98 (0.98-0.99)	<.001
Restraint type		
Air bag	1.02 (0.50-2.13)	.94
Seat belt	0.24 (0.14-0.42)	<.001
Seat belt and air bag	0.16 (0.07-0.38)	<.001
Unrestrained	1 [Reference]	
Crash partner		
Auto vs LTV	1.13 (0.52-2.45)	.75
LTV vs Auto	0.83 (0.37-1.85)	.65
LTV vs LTV	0.99 (0.48-2.04)	.99
Auto vs non-Auto	2.38 (1.00-4.74)	.01
Auto vs Auto	1 [Reference]	

Abbreviations: Auto, automobile; CI, confidence interval; LTV, light truck, sports utility vehicle, or van; OR, odds ratio; ΔV, amount of velocity lost by vehicle due to collision.

<sup>a</sup>Adjusted for impact type, sex, height, weight, restraint type, ΔV, and crash type.

this study due to the lack of a police report or a towed vehicle. In addition, the data may be subject to reporting bias. The majority of our study fractures fall into the maximum abbreviated injury score 1 to 3 range, which represent minor to moderate injuries. Blincoe et al<sup>3</sup> estimated that the reporting rate for these types of injuries ranged from 75% to 92%, suggesting that nasal fractures may be underreported in this series. Other limitations include the arbitrary nature of our designated fracture categories and missing data, particularly ΔV values. While we attempted to compensate for missing ΔV data using multiple imputation methods, this remains a notable limitation in the NASS data.

## CONCLUSIONS

Overall, the probability of facial fractures from MVCs is decreasing over time. This may be due to design improvements implicitly related to advancing crash technology available in newer vehicle model years. Restraint use continues to be the most significant element for facial and skull base injury prevention, and more research is necessary to elucidate the mechanisms for facial and skull base fractures in side impacts, as well as to determine the effectiveness of side impact supplemental restraint systems. Furthermore, factors such as changes in vehicle fleet composition may alter injury trends. Further study is required to assess the role of occupant factors such as age, sex, and body mass on injury mechanism and risk.

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## REFERENCES

1. Nakhgevany KB, LiBassi M, Esposito B. Facial trauma in motor vehicle accidents: etiological factors. *Am J Emerg Med.* 1994;12(2):160-163.
2. Haug RH, Adams JM, Conforti PJ, Likavec MJ. Cranial fractures associated with facial fractures: a review of mechanism, type, and severity of injury. *J Oral Maxillofac Surg.* 1994;52(7):729-733.
3. Blincoe L, Seay A, Zaloshnja E, et al. *The Economic Impact of Motor Vehicle Crashes, 2000.* Washington, DC: National Highway Traffic Safety Administration, US Dept of Transportation; 2002. Report DOT HS 809 446.
4. Cox D, Vincent DG, McGwin G, MacLennan PA, Holmes JD, Rue LW III. Effect of restraint systems on maxillofacial injury in frontal motor vehicle collisions. *J Oral Maxillofac Surg.* 2004;62(5):571-575.
5. Simoni P, Ostendorf R, Cox AJ III. Effect of air bags and restraining devices on the pattern of facial fractures in motor vehicle crashes. *Arch Facial Plast Surg.* 2003;5(1):113-115.
6. Mouzakes J, Koltai PJ, Kuhar S, Bernstein DS, Wing P, Salsberg E. The impact of air bags and seat belts on the incidence and severity of maxillofacial injuries in automobile accidents in New York State. *Arch Otolaryngol Head Neck Surg.* 2001;127(10):1189-1193.
7. Kent R, Funk J, Crandall J. How future trends in societal aging, air bag availability, seat belt use, and fleet composition will affect serious injury risk and occurrence in the United States. *Traffic Inj Prev.* 2003;4(1):24-32.
8. Toy EL, Hammitt JK. Safety impacts of SUVs, vans, and pickup trucks in two-vehicle crashes. *Risk Anal.* 2003;23(4):641-650.
9. Martin PG, Crandall JR, Pilkey WD. Injury trends of passenger car drivers in frontal crashes in the USA. *Accid Anal Prev.* 2000;32(4):541-557.
10. Grant JR, Rhee JS, Pintar FA, Yoganandan N. Modeling mechanisms of skull base injury for drivers in motor vehicle collisions. *Otolaryngol Head Neck Surg.* 2007;137(2):195-200.
11. National Highway Traffic Safety Administration. National Automotive Sampling System: Crashworthiness Data System, 1993-2005 [database on CD-ROM]. Washington, DC: Dept of Transportation; 2005.
12. Robertson LS. Further reflections on the seat belt use and effectiveness issue. *Inj Prev.* 2003;9(3):284-285.
13. Association for the Advancement of Automotive Medicine, Committee on Injury Scaling. *Association for the Advancement of Automotive Medicine, Committee on Injury Scaling. The Abbreviated Injury Scale: 1990 Revision (AIS-90).* Des Plaines, IL: Association for the Advancement of Automotive Medicine; 1990.
14. McGwin G Jr, Metzger J, Porterfield JR, Moran SG, Rue LW III. Association between side air bags and risk of injury in motor vehicle collisions with near-side impact. *J Trauma.* 2003;55(3):430-436.
15. Brookes CN. Maxillofacial and ocular injuries in motor vehicle crashes. *Ann R Coll Surg Engl.* 2004;86(3):149-155.
16. Francis DO, Kaufman R, Yueh B, Mock C, Nathens AB. Air bag-induced orbital blow-out fractures. *Laryngoscope.* 2006;116(11):1966-1972.

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