

Basilar Skull Fractures by Crash Type and Injury Source

2011-01-1126

Published
04/12/2011

Chantal Parenteau and David C. Viano
ProBiomechanics LLC

Copyright © 2011 SAE International

doi:10.4271/2011-01-1126

ABSTRACT

Purpose: This study investigates NASS-CDS data on basilar skull fractures by crash type and injury source for various crash scenarios to understand the injury risks, injury mechanisms and contact sources.

Methods: 1993-2008 NASS-CDS data was used to study basilar skull fractures in adult front occupants by crash type and injury source. Injury risks were determined using weighted data for occupants with known injury status in 1994+ model year vehicles. In-depth analysis was made of far-side occupants in side impacts and rear crashes using the NASS electronic cases.

Results: Basilar skull fractures occur in $0.507 \pm 0.059\%$ of rollovers and $0.255 \pm 0.025\%$ of side impacts. The lowest risk is in rear impacts at $0.015 \pm 0.007\%$. The most common contact source is the roof, side rails and header (39.0%) in rollovers, the B-pillar (25.8%) in side impacts and head restraint (55.3%) in rear crashes. Seatbelt use significantly lowers the risk for basilar fracture from $1.77 \pm 0.32\%$ for unbelted to $0.20 \pm 0.03\%$ for belted ($p < 0.001$) near-side occupants and from $0.92 \pm 0.19\%$ for unbelted to $0.057 \pm 0.012\%$ for belted ($p < 0.001$) far-side occupants in side impacts. The electronic cases show basilar fractures typically occur in very severe crashes with high delta V and intrusion.

Conclusions: Basilar skull fractures occur in $9.7 \pm 0.9\%$ of the crashes where an occupant experiences an AIS 3+ head injury. NASS case reviews show that basilar fractures typically occur in very severe crashes with multiple head injuries from contact with hard surfaces or by components stiffened from intrusion.

INTRODUCTION

One of the serious skeletal injuries in automotive crashes is basilar skull fracture. They occur at the base of the skull and can have a linear, ring or complex fracture pattern. They have been associated with a number of different injury mechanisms, including 1) impact of the side or back of the head (Gurdjian et al. 1961, Pintar et al. 2007, Shanahan 1983), 2) impact on the top of the head (Sances et al. 1986, Myers, Nightingale et al. 1999, Alem et al. 1982, 1984), 3) impact to the face or chin forcing the mandible rearward into the skull (Huelke et al. 1988, Hopper et al. 1994, Harvey, Jones 1980, McElhaney et al. 1995), and 4) head inertia pulling on the neck (Hubbard et al. 1994).

While basilar skull fractures are usually associated with a short duration loading of the skull from a hard impact surface, they have also occurred with airbag loading of the face of an occupant in close proximity to a deploying airbag (Bandstra, Carbone 2001, Perez, Palmatier 1996). Basilar skull fractures often occur with other brain injuries and can involve brain stem, atlanto-occipital joint and other cervical injuries (Tepper et al. 1990). The basilar fracture pattern and mechanism of injury may depend on the tension forces in the neck. Basilar fractures are also a common head injury in children (Liu-Shindo, Hawkins, 1989).

This study addresses the risk for basilar skull fracture by crash type and includes two in-depth investigations of basilar fracture scenarios. One involves near- and far-side occupants in side impacts and considers the risk for basilar fracture by belt use. Based on this analysis, a special investigation of NASS-CDS electronic cases was conducted of far-side occupants experiencing basilar fractures from B-pillar contact. The other investigation explores the injury source for basilar skull fractures in rear impacts. This was prompted by the head restraint being a source of fracture and a question on

how the injury occurs. Other scenarios of basilar fracture were not considered by in-depth investigation in this paper, such as basilar fractures occurring in rollovers or frontal impacts.

METHODS

NASS-CDS data for calendar years 1993-2008 was used to study basilar skull fractures in front outboard occupants (seatpos = 11 or 13) by crash type and injury source. NASS-CDS is a stratified sample of fatal, injury and tow-away crashes without injury that are prospectively selected each year for in-depth investigation. Most of the vehicles are towed from the scene because of damage. The data includes information from NASS crash investigation teams, vehicle registration, medical records, the police report and interviews.

The data was extrapolated to national estimates for the number of occupants and injuries in each category using the Ratio Weight (ratwgt) variable in NASS-CDS. All calculations were based on weighted data. Standard errors were determined in SAS. Front-seat occupants were 13-104 years old. Only towaway (towpar=1), light vehicles with model year 1994+ were included.

Crash types were defined as:

- Front: Vehicles involved in frontal impacts where the greatest damage was to the front (GAD1 = F). Collisions in which a rollover occurred were excluded from the sample (Rollover ≤ 0).
- Side: Vehicles involved in side impacts where the greatest damage was to the left or right side (GAD1= L or R). Collisions in which a rollover occurred were excluded from the sample (Rollover ≤ 0).
- Rear: Vehicles involved in rear impacts where the greatest damage was to the rear (GAD1=B). Collisions in which a rollover occurred were excluded from the sample (Rollover ≤ 0).
- Rollover: Vehicles involved in rollover were those with a rollover > 0 .
- Other: Vehicles involved in other impacts where the greatest damage was to the top or undercarriage (GAD1=U or T). Collisions in which a rollover occurred were excluded from the sample (Rollover ≤ 0).
- Unknown: Vehicles involved in impacts with unknown damage information.

Injury severity of the occupant was assessed using the Maximum Abbreviated Injury Scale (MAIS) and the "TREATMNT" variable. MAIS represents the assessment of life-threatening injuries at the time of first medical evaluation and not long-term consequences. It ranges from MAIS 0 to 9. MAIS 3-6 represents a serious-to-un survivable injury and

MAIS 4-6, a severe-to-un survivable injury. Fatality was also used to determine if the occupant died of injuries in the accident. The variable "TREATMNT" was used to define fatality, which is TREATMNT = 1. Because fatalities can occur at any MAIS level, seriously injured occupants were defined as those with MAIS 3-6 or fatality and severely injured, as those with MAIS 4-6 or fatality. The shorthand notation is MAIS 3+F and MAIS 4+F, respectively.

Basilar skull fractures were typically classified as serious-to-fatal injury (AIS 3+) to the lower skull (region90 = 1 (head), aspect = 8 (inferior) and strutype = 5 (skeletal)). Most basilar skull fractures were AIS 3. In some cases, a complex basilar fracture was AIS 4. The fracture could be listed as an injury associated with the occupant's death, although this was infrequent as other more severe brain injuries typically occurred.

The risk for injury was determined by dividing the number of basilar fractures by the number of occupants with known injury status, MAIS 0-6 or F (MAIS 0+F). Occupants with unknown injury status were removed from the exposure group used to determine risk. This study also focused on side impacts and analyzed the risk of basilar skull fracture for near-seated (near-side) and far-seated (far-side) occupants by belt use and injury source.

Belt use was defined by the NASS-CDS investigator's variables MANUSE (manual (active) belt system use) and ABELTUSE (automatic (passive) belt system use). Unbelted was defined as MANUSE ≤ 1 (blank, inoperative or none used/available) and ABELTUSE < 1 (blank, inoperative or not equipped/available) or ABELTUSE=2 (belt not in use). Belted was defined as MANUSE=4 (lap and shoulder belt).

Individual NASS-CDS electronic cases were downloaded from the 1997-2008 NASS-CDS online files to gain an understanding of basilar skull fracture mechanisms in two different scenarios. Six severely injured far-seated occupants were found with basilar skull fractures due to B-pillar contact in side impacts. These cases were reviewed to understand the crash severity and circumstances for the injury. Eight cases with basilar skull fracture in rear impacts were also downloaded to explore the mechanism for basilar fracture of front-seated occupants.

Table 1. NASS-CDS Data for Adult, Front-Outboard Occupants with Basilar Skull Fractures by Crash Type and Injury Source.

Front Occupants	Front	Side	Rear	Rollover	Other	Unknown	Total
Vehicles involved	11,030,000	4,856,980	1,542,612	2,070,923	165,984	6,190,052	25,856,551
Front outboard occupants	13,360,000	6,089,670	1,937,919	2,593,025	198,960	7,329,028	31,508,602
MAIS 0+F	12,920,000	5,860,838	1,838,557	2,467,484	188,073	6,644,948	29,919,900
MAIS 3+F	281,883	175,731	8,176	169,788	12,295	74,233	722,106
MAIS 4+F	75,767	85,704	5,242	85,403	7,151	30,969	290,235
Head AIS 3+ injuries	104,890	167,011	11,951	130,657	16,172	53,561	484,240
Basilar skull fracture	11,796	14,927	270	12,522	2,406	5,004	46,925
SE	3,946	1,441	122	1,452	895	976	4,442
Injury sources for basilar skull fracture							
Seatback	0	97	0	0	0	0	97
Head restraint	0	148	149	0	0	0	297
A-Pillar	1,054	593	0	189	45	517	2,399
B-Pillar	400	3,758	0	257	0	330	4,746
Side window	0	252	0	58	0	0	310
Side interior/door	199	900	51	28	0	80	1,258
Roof/side rail/header	1,140	1,735	36	4,417	646	192	8,167
Windshield (WS)	552	131	0	22	0	9	714
WS with pillars, header, other	114	296	0	634	0	0	1,358
WS reinforced by ext object	214	0	0	0	0	0	214
Steering wheel	1,593	0	0	789	0	65	2,446
Instrument panel	4,176	48	0	3	0	1	4,228
Other components	569	434	0	336	347	0	1,371
Other occupants	13	430	0	45	0	0	488
Other vehicle/object	924	1,714	8	624	0	792	4,064
Ground/environment	522	4,005	26	3,932	568	383	9,435
Unknown	326	385	0	1,189	800	2,634	5,334
Total	11,796	14,927	270	12,522	2,406	5,004	46,925

RESULTS

BASILAR SKULL FRACTURE BY CRASH TYPE

Table 1 summarizes weighted NASS-CDS counts for vehicles and occupants involved in front, side, rear and rollover crashes. For known accident types, 55.3% of the occupants were involved in frontal crashes (13,360,000) and 25.2% (6,089,670) in side impacts. Smaller fractions were involved in rollovers (10.7%), rear impacts (8.0%) and other crash types (0.8%). The number of occupants experiencing MAIS 3+F and MAIS 4+F is listed as well as the number of occupants experiencing AIS 3+ head injuries.

Overall, there were 484,240 AIS 3+ head injuries and 46,925 basilar skull fractures. Most basilar fractures occurred in side impacts (14,927) or rollovers (12,522). The source for the basilar fracture is given based on the investigation by the NASS-CDS teams. Twelve interior components are listed as possible sources for the basilar fracture along with contact with another occupant in the vehicle. The source can also include exterior objects, another vehicle component and the ground for occupants that partially or fully eject from the vehicle.

Table 2 shows the risk of basilar fracture by crash type. Overall, 1.62% of occupants experienced AIS 3+ head injury and 0.157% had a basilar skull fracture. The highest risk for basilar fracture occurred in the other crash category (1.279%), which includes roof damage. Rollover crashes (0.507%) were the second leading cause followed by side impacts (0.255%). For seriously-to-fatally injured occupants (MAIS 3+F), $6.50 \pm 0.62\%$ experienced a basilar skull fracture. The rate was $8.49 \pm 0.82\%$ in side impacts.

Figure 1 shows the risk for basilar skull fracture by crash type and includes the standard errors in risk. The risk for basilar skull fracture was significantly different among the four crash types. The highest risk was $0.507 \pm 0.059\%$ in rollovers followed by $0.255 \pm 0.025\%$. The lowest risk was in rear impacts ($0.015 \pm 0.007\%$). **Figure 1** also lists the distribution of basilar skull fractures by crash type (excluding unknown). Frontal impacts are associated with 28.1% of the basilar fractures, side impacts at 35.6% and rollovers at 29.9%.

Table 2. Risk of Adult, Front-Outboard Occupants with Basilar Skull Fracture by Crash Type and Percentage of Injury Sources.

Front Occupants	Front	Side	Rear	Rollover	Other	Unknown	Total
% MAIS 3+F/MAIS 0+F	2.2%	3.0%	0.44%	6.9%	6.5%	1.1%	2.4%
% MAIS 4+F/MAIS 0+F	0.59%	1.5%	0.29%	3.5%	3.8%	0.5%	1.0%
% Head AIS 3+ injury	0.81%	2.85%	0.65%	5.30%	8.60%	0.81%	1.62%
% Basilar skull fracture	0.091%	0.255%	0.015%	0.507%	1.279%	0.075%	0.157%
%SE	0.031%	0.025%	0.007%	0.059%	0.476%	0.015%	0.015%
Basilar fx./MAIS 3+F	4.18%	8.49%	3.30%	7.38%	19.57%	6.74%	6.50%
SE	1.40%	0.82%	1.49%	0.86%	7.28%	1.32%	0.62%
Basilar fx./AIS 3+ head injury	11.2%	8.9%	2.3%	9.6%	14.9%	9.3%	9.7%
SE	3.8%	0.9%	1.0%	1.1%	5.5%	1.8%	0.9%
% basilar skull fracture by injury source							
Seatback	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.2%
Head restraint	0.0%	1.0%	55.3%	0.0%	0.0%	0.0%	0.7%
A-Pillar	9.2%	4.1%	0.0%	1.7%	2.8%	21.8%	5.8%
B-Pillar	3.5%	25.8%	0.0%	2.3%	0.0%	13.9%	11.4%
Side window	0.0%	1.7%	0.0%	0.5%	0.0%	0.0%	0.7%
Side interior/door	1.7%	6.2%	18.8%	0.2%	0.0%	3.4%	3.0%
Roof/side rail/header	9.9%	11.9%	13.3%	39.0%	40.2%	8.1%	19.6%
Windshield	4.8%	0.9%	0.0%	0.2%	0.0%	0.4%	1.7%
WS with pillars, header, other	1.0%	2.0%	0.0%	5.6%	0.0%	0.0%	3.3%
WS reinforced by ext object	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
Steering wheel	13.9%	0.0%	0.0%	7.0%	0.0%	2.8%	5.9%
Instrument panel	36.4%	0.3%	0.0%	0.0%	0.0%	0.0%	10.2%
Other components	5.0%	3.0%	0.0%	3.0%	21.6%	0.0%	3.3%
Other occupants	0.1%	3.0%	0.0%	0.4%	0.0%	0.0%	1.2%
Other vehicle/object	8.1%	11.8%	3.1%	5.5%	0.0%	33.4%	9.8%
Ground/environment	4.5%	27.5%	9.5%	34.7%	35.4%	16.2%	22.7%
Unknown							
Total	100%	100%	100%	100%	100%	100%	100%

The percent of basilar skull fracture by contact source is listed in Table 2 by crash type. For example, the largest fraction of basilar fractures occurs by impact with the B-pillar (25.8%) and the ground (27.5%) in side impacts. The leading sources for basilar fracture vary by the type of crash. In rollovers, the leading source is the roof, side rails or header structures (39.0%) of the vehicle. For rear impacts, 55.3% of the basilar fractures were associated with the head restraint.

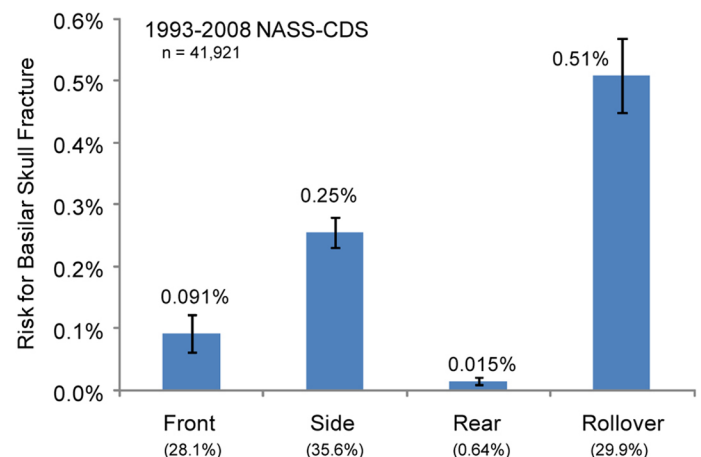


Figure 1. Risk for basilar skull fracture by crash type (percents in parentheses represent the distribution of basilar skull fractures among known crash types).