

FREQUENCY OF INJURIES IN MULTIPLE IMPACT CRASHES

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ABSTRACT

NASS 1998-2000 was queried to determine the frequency of serious injuries in multiple impact crashes and the distribution of injuries by crash sequence. The data set included all passenger cars and light trucks in NASS/CDS.

The results showed that 42% of the MAIS 3+ injuries were in crashes that involved more than one harmful event. Approximately 24% of the MAIS 3+ injuries involved two harmful events, and 18% involved 3 or more harmful events.

For multiple crashes with serious injuries, the most frequent initial impact direction was frontal (50%) followed by side (44.9%). The most frequent second impact was side (48.4%) followed by frontal (27.6%). The most harmful sequences were side-side (27.7%), front-side (15.8%) and front-front (14.9%).

The data suggests the need for further investigation and classification complex multiple impact crashes to aid in the in the design of safety systems.

Motor vehicle crashes are normally divided into four categories – frontal, side, rear and rollover. In reality, crashes are not that simple. Crashes that involve more than one harmful event are the source of a large fraction of the MAIS 3+ injuries. The category of crashes that involves more than one harmful impact is classified as multiple impact crashes.

To compare US multiple impact crashes with single impact crashes, the NASS/CDS database for the years 1998-2000 was queried. All passenger cars and light trucks were included in the query. Each impact was classified by principal area of damage. The crash direction was assumed to correspond to the area of the vehicle damaged. Rollovers were assumed to be associated with top damage.

The MAIS 3+ injury distributions for the exposed occupants were examined for all crash combinations. The injuries reported in multiple impacts are those involving a case vehicle that was subjected to the multiple crashes. The injuries sustained by occupants of other vehicles that may have been involved were classified according to the direction and number of impacts for that vehicle.

RESULTS

The NASS/CDS represents approximately 4.7 million tow-away crashes per year that involve approximately 108,000 MAIS 3+ injured occupants.

Table 1 shows the distribution of crashes, MAIS 3+ injured occupants and MAIS 3+ injury rate per 100 exposed for single and multiple impact crashes. Multiple impact crashes represent only 24% of the crashes but 42% of the MAIS 3+ injuries. The MAIS 3+ injury rate is stated in terms of the number of people with MAIS 3+ injuries per 100 exposed to the crash mode.

Table 1- Single vs. Multiple Impact; by Number of Crashes, MAIS 3+ Injuries, and MAIS 3+ Injury Rate per 100 Exposed

Crash Mode	People %	MAIS 3+ %	Rate
Single Impact Crashes	76%	58%	1.74
Multiple Impact Crashes	24%	42%	4.03

A break out by direction of damage and number of impacts is shown in Table 2. Multiple impact crashes represent the largest fraction of MAIS 3+ injured occupants. Frontal crashes are second with 32%. Crashes involving three or more impacts account for 18% of the MAIS 3+ injured occupants.

Table 2- Distribution by Crash Direction, Number of Crashes, MAIS 3+ Injuries, and MAIS 3+ Injury Rate per 100 Exposed

Crash Mode	People %	MAIS 3+ %	Rate
Front Single	45%	32%	1.65
Back Single	5%	1.0%	0.42
Side Single	21%	17%	1.79
Top Single	5%	8%	3.85
Two Impacts	17%	24%	3.21
Three+ Impacts	6%	18%	6.25

Table 3 shows the distribution of MAIS 3+ injured occupants in all multiple-impact crashes. This group represents 42% of all MAIS 3+ injuries. Fifty percent of MAIS 3+ injuries in multiple

impact crashes occur in crashes with an initial frontal impact. An initial side impact occurs in 44.9% of the multiple impact crashes. The most frequent second impact was side (48.4%) followed by frontal (27.6%). Rollovers were the second event in 8.2% of the multiple impact crashes with MAIS 3+ injuries. Table 4 lists the rate of MAIS 3+ injuries per 100 exposed for the most common multiple crash modes.

Table 3- Distribution of MAIS 3+ Injuries by 1st and 2nd Impact; All Multiple-Impact Crashes

	Second Impact				
<u>First Impact</u>	Front	Side	Top	Rear	Total
<u>Front</u>	18.5%	19.3%	10.2%	2.2%	50.1%
<u>Side</u>	7.5%	26.9%	8.4%	2.1%	44.9%
<u>Top</u>	0.6%	1.1%	0.4%	0.1%	2.2%
<u>Rear</u>	1.0%	1.0%	0.6%	0.1%	2.8%
<u>Total</u>	27.6%	48.4%	19.6%	4.5%	100.0%

Table 4- Rate of MAIS 3+ Injuries per 100 Exposed, by 1st and 2nd Impact; All Multiple-Impact Crashes

	Second Impact				
<u>First Impact</u>	Front	Side	Top	Rear	All
<u>Front</u>	3.5	4.0	8.0	3.4	4.2
<u>Side</u>	2.6	5.2	10.6	4.7	4.8

Table 5 shows the injury data for crashes that involve only two impacts. These crashes account for 24% of the MAIS 3+ injuries. The data in Table 5 is normalized to add to 100%. For these crashes, side impacts account for the largest fraction of injuries – both as the 1st impact (45.8%) and as the 2nd impact (51.2%). The crash type in which the most injuries occur is a side impact followed by a second side impact (27.7%). The second most harmful mode is a front impact, followed by a side impact. Frontal followed by frontal and side followed by roll are other harmful crash combinations.

Table 6 shows the data for crashes that involve more than two impacts. These crashes account for 18% of the MAIS 3+ injuries. For this population of injured occupants, side impacts continue to account for the largest fraction of injuries as the 2nd impact (51.9%). However, for the 1st impact, frontal crashes account for the largest fraction of injuries (58.9%). The frontal impact is more frequently the initial impact direction in the 3+ impact category than it is in the two impact category (43.7%).

**Table 5- Distribution of MAIS 3+ Injuries by 1st and 2nd Impact;
Multiple-Impact Crashes with Only 2 Impacts**

	Second Impact				
First Impact	Front	Side	Top	Rear	Total
Front	14.9%	15.8%	9.7%	3.3%	43.7%
Side	9.9%	27.7%	12.5%	1.1%	51.2%
Top	0.0%	1.2%	0.5%	0.1%	1.8%
Rear	1.3%	1.0%	0.9%	0.0%	3.3%
Total	26.1%	45.8%	23.7%	4.4%	100.0%

**Table 6- Distribution of MAIS 3+ Injuries by 1st and 2nd Impact;
Multiple-Impact Crashes with 3+ Impacts**

	Second Impact				
First Impact	Front	Side	Top	Rear	Total
Front	23.4%	24.1%	10.8%	0.7%	58.9%
Side	4.3%	25.9%	2.6%	3.6%	36.3%
Top	1.4%	1.0%	0.3%	0.1%	2.7%
Rear	0.6%	1.0%	0.2%	0.2%	2.0%
Total	29.6%	51.9%	13.9%	4.5%	100.0%

BELTED VS. UNBELTED

Table 7 shows the distributions for belted and unbelted occupants by the crash mode to which they were exposed. The table shows the exposed occupants, the MAIS 3+ injuries and the injury rate per 100 exposed.

Table 8 shows the distributions for belted and unbelted occupants by crash direction and number of impacts. The belted have lower percentages of MAIS 3+ injuries in frontals and in multiple impacts. However, belted have higher percentages in single side impacts.

Table 7- Single vs. Multiple Impact for Belted and Unbelted; by Number of Crashes, MAIS 3+ Injuries, and MAIS 3+ Injury Rate per 100 Exposed

	Belted		
Crash Mode	People %	MAIS 3+ %	Rate
Single Impact Crashes	77%	60.5%	1.13
Multiple Impact Crashes	23%	39.5%	2.47
	Unbelted		
Crash Mode	People %	MAIS 3+ %	Rate
Single Impact Crashes	71%	54%	5.39
Multiple Impact Crashes	29%	46%	10.81

Table 8- Distribution by Crash Direction; Single vs. Multiple Impact for Belted and Unbelted; by Number of Crashes, MAIS 3+ Injuries, and MAIS 3+ Injury Rate per 100 Exposed

	Belted			Unbelted		
Crash Mode	People	MAIS 3+	Rate	People	MAIS 3+	Rate
Front Single	45%	29%	0.93	39%	33%	5.92
Back Single	6%	1.4%	0.34	3%	0.7%	1.89
Side Single	22%	21%	1.36	19%	13%	4.76
Top Single	4%	10%	3.15	11%	8%	5.42
Two Impacts	17%	24%	2.08	21%	25%	8.36
Three+ Impacts	6%	15%	3.52	9%	21%	16.69

Table 9- Distribution of MAIS 3+ Injuries by 1st and 2nd Impact; All Multiple-Impact Crashes Belted Occupants Only

	Second Impact				
First Impact	Front	Side	Top	Rear	Total
Front	21.0%	14.4%	5.0%	3.6%	44.1%
Side	10.6%	29.2%	8.4%	2.7%	50.9%
Top	1.1%	0.8%	0.3%	0.0%	2.2%
Rear	1.3%	0.3%	1.1%	0.1%	2.8%
Total	34.0%	44.8%	14.8%	6.4%	100.0%

Table 9 shows the distribution of MAIS 3+ injuries for belted occupants by 1st and 2nd impact. The distribution for belted is generally similar to the overall distribution in Table 3. However, for the second impact, belted have fewer injuries in rollovers and more injuries in frontals. For belted occupants 39.5% of the MAIS 3+ injuries involve multiple impacts. Side impacts are the most hazardous second impact, accounting for 44.8% of the injuries.

Multiple side impacts account for 29.2% of the injuries. Multiple frontal impacts are also hazardous, accounting for 21% of the MAIS 3+ injuries.

DISCUSSION

In the US data, 24% of occupants were exposed to multiple impacts. This compares to 26.5% in German data, and 29.0% in UK data. [Fay, 2001].

Multiple impacts account for 42% of the MAIS 3+ injuries in NASS/CDS 1998-2000. This compares to 43% in German data and 30% in UK data [Fay, 2001]. US data shows that for belted occupants, 29% of the MAIS 3+ injuries are in frontal crashes while 39% are in multiple impact crashes (Table 8).

Temming [1998] analyzed crashes in Germany with cervical spine distortion injuries and found that the multiple impact crash mode produced a relatively high frequency and high risk of these injuries, compared with other crash modes.

The large fraction of MAIS 3+ injuries that occur in multiple impact crashes is a growing concern to safety researchers in UK and Germany [Fay, 2001]. Present safety standards evaluate safety features only in relatively simple frontal and side crashes. Testing of the performance of safety systems in the more complex multi-impact modes is virtually non-existent in the public literature. Safety systems designed to single impact crashes may lose effectiveness in multiple impacts. More detailed analysis of multiple impact crashes is needed to set priorities for occupant protection in these complex events.

CONCLUSIONS

For the population of MAIS 3+ injured in multiple impact crashes, the most dominant initial crash direction was frontal. The data indicates that 50.1% of MAIS 3+ multiple impacts involve a frontal crash as the first impact. About 18.5% of occupants with MAIS 3+ injuries were subsequently exposed to a second frontal crash and 19.3% were subsequently exposed to a side crash. The remainder were exposed to rear crashes or rollovers. The most dominant second impact was the side, accounting for 48.4% of MAIS 3+ injuries.

Crashes that involve only 2 impacts account for 24% of the MAIS 3+ injuries. Crashes involving 3 or more impacts account for 18% of the MAIS 3+ injuries.

For belted occupants, 39.5% of the MAIS 3+ injuries involve multiple impacts. The crash combinations associated with the largest fractions of MAIS 3+ injuries were as follows: side impact followed

by side impact (29.2%), front impact followed by front impact (21.0%), front impact followed by side impact (14.4).

The frequency of injuries in multiple impacts and the lack of test and evaluations indicate the need to examine this class of crashes in more detail. Further research should focus on the combination of crashes with the highest number of injuries and an associated increased injury rate. Priorities for restrained occupants should be crashes involving a frontal or side component followed by a side component, and on crashes with multiple frontal impacts.

REFERENCES

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Temming, J. and Zobel, R., Frequency and Risk of Cervical Spine Distorsion Injuries in Passenger Car Accidents: Significance of Human Factors Data. IRCOBI Proceedings, 1999.