COMPARISON OF INJURY SEVERSITY BETWEEN NEAR AND FAR SIDE OCCUPANTS ON THE SIDE COLLISIONS

Younghan Youn
Jiyang Park
Korea University of Technology and Education, Korea, Republic of
Daeup Kim
Siwoo Kim
Jeongmin In
Korea Automotive Testing and Research Institute, Korea, Republic of

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ABSTRACT

Side collision accidents were the most frequent and fatal traffic accidents in Korea. The safety regulations and KNCAP (MDB and Pole side test) only protect the near side driver. Since 2003, the safety standard and KNCAP were established to protect occupants from the side collision type accidents in Korea. However, from 2014 police accident data, fatalities from side collision type of accidents were 555 and the ratio was 30%. The injured occupants were 92,300 and ratio was 34%. In this police data, all fatality and injury of participants that involved this accident were counted even though one who experienced frontal structure of vehicle was impacted.

The objective of this study was to investigate the severity of side impacts in KIDAS. Recently, KIDAS (Korea In-Depth Accident Study) has been established and collected the accident data from four different medium size cities from 2012. Among 2,080 cases of all accidents, 217 cases of side impacts were investigated. In this data analysis, seated position, vehicle damage, impact speed, impact direction, vehicle type, gender, age, height and weight were selected as influence variables to identify the severity of injury and injured body parts. From the limited real accident data analysis, the number of accident and injury severity between near and far side impact were almost equivalent.

The side impact test with far-side seated dummy was conducted and analyzed to compare with near side impact test results. On the comparison, both dummy injury and kinematics was investigated.

In the paper, the test results for injury severity for near and far side occupants were compared as well as the kinematic behavior of dummy motions. New assessment criteria for far side occupant in side impact was proposed as KNCAP far side occupant protection test method and effectiveness of the center air bag system

INTRODUCTION

The main objective of both side impact research and side impact regulation to date has been to protect occupants located on the struck side of a passenger vehicle. However, occupants of the non struck, or far side, of the vehicle are also at risk of injury. The mechanism of far side impact injury is believed to be quite different than that for near side impact injury. Far side impact protection may require the development of different countermeasures than those which are effective for near side impact protection.

From side crashes, caused by a car or truck or by a rigid object impact, the driver is still the most dominant and frequently injured occupant, yet for front seated occupants, near and far side crashes seem equally dominant in terms of fatalities. Not until recently, there was not much of researches in far side analysis and test criteria, this crash mode has not been addressed by safety regulations or consumer information ratings. An extensive international collaborative research project on far side safety has been conducted in 2009 [1].

There have been a number of international and US studies of far-side crash data that can provide a basis for comparing how the safety environment in far-side crashes has changed. Gabler [2] analyzed NASS CDS 1993-2002 data, showed that the median lateral delta-

V for belted front seat occupants exposed to a far side impact was 12 km/hr. The median lateral delta-V for serious (AIS 3+) injuries was 28 km/hr. A principal direction of force of 60 degrees was most likely to be associated with serious injury. A PDOF of 60 degrees +/- 15 degrees were experienced by 60% of the seriously injured persons.

The body regions with the highest number of AIS 3+ injuries were: chest/abdomen, 41% and head/face, 32%. The contacts for AIS 2+ head injuries were widely distributed with no source exceeding 10%. AIS 2+ head injuries from contacts with other occupants constituted 4.8% of the injuring sources. Unlike head injuries, the contacts for AIS 2+ chest and abdominal injuries were concentrated. For AIS 2+ chest injuries, 48% were attributed to the seat back and 24% to the safety belt. For AIS 2+ abdominal injuries, 87% of injury were caused by the safety belt.

The use of the most recent ten years of NASS data permitted an update of the characteristics of far-side crashes that are associated with serious injuries among belted front seat occupants [3]. For the 2004-2013 NASS CDS data, the median crash severity for MAIS 3+ injured was a lateral delta V of 36 kph. Chest/abdominal injuries accounted for 43% and head injuries accounted for 23% of the AIS 3+ injuries. Drivers accounted for 79% of the MAIS 3+ injured belted front outboard occupants that were involved in far-side crashes. About 53% of front outboard occupant's chest injuries were caused by contacts with the vehicle center stack or seat back and 21% were associated with contacts with the far-side structure. In regards to head injuries, the far side structure accounts for more than 60% of the AIS 3+ injuries.

Of the far side crash involved occupants analyzed, they sustained AIS3+ head or chest injuries from the far side of the vehicle more than 4.4 times more often than were attributed to occupant to occupant contact. Another striking trend is the disproportionate number of AIS3+ injured occupants in light passenger cars where belted front outboard occupants sustained severe injuries at a rate 2.7 times higher than exposed. Finally, this study identified that only 3.1% of belted AIS3+ injured occupants involved in far-side collisions sustained their injuries due to occupant to occupant contact with another front seat occupant [4].

MOTIVATION

From KNCAP side crash test analysis, the probability of serious injury (AIS 3 +) for the near side occupant (driver) was 11.3% in 2003. In 2013, the average severity dramatically dropped to 2.0% as shown in Figure 1. However, from 2014 police accident data, fatalities from side collision type of accidents were 555 and the ratio was 30%. The injured occupants were 92,300 and ratio was 34%. According to police accident classification, all fatality and injury of participants that involved this type of accident were counted as victims of side collision, even though one who experienced head-on type (frontal structure of vehicle) accident.

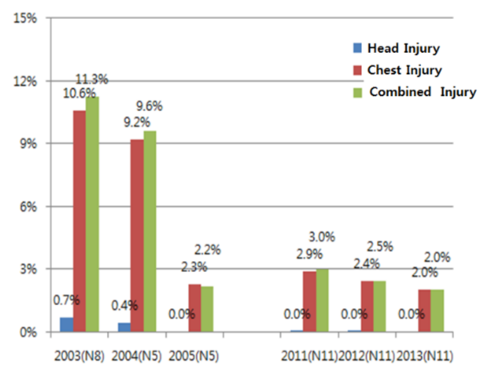

Figure 1. KNCAP side impact performances

ANALYSIS OF NEAR AND FAR SIDE INJURIES IN KIDAS

An objective of this study was to examine injury patterns for the far-side front seated occupants in lateral collisions. From the results of current works, it is intension to the further amendment of KNCAP roadmap to protect far-side front seated occupants in the event of lateral collisions. In this research works, it will be included various crash tests and simulations to understand and the occupant kinematics that cause the most frequent injuries as well as developing countermeasures in terms of a protection system to significantly reduce these injuries from far-side side impact accidents.

In a KIDAS of vehicle-patients query from 2012-2015, near-side occupants were defined as front seated occupants whether drivers or passengers who had been experienced their sides were struck. On the other hand, far-side occupants were defined as front left passenger with right side damage and principle direction of force (PDOF) from 2 o'clock to 4 o'clock direction or front right passenger with left side damage and PDOF from 8 o'clock to 10 o'clock direction as shown in Figure 2.

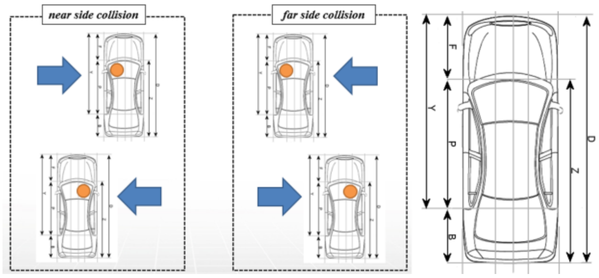

Figure 2. Near and Far side collisions

From KIDAS, 98 Vehicles of real-road side collision accidents were extracted and investigated. In this study, seated positions, vehicle damages, impact speeds, impact directions, vehicle types, genders, ages, heights and weights were selected as influence variables to identify the severity of injury and injured body parts.

Among the data set, 47 vehicles were near side accidents and 51 vehicle were far side accidents.
Vehicle damaged patterns from CDC code, the damage position P which occurs at the middle part of lateral side vehicle, the average of thorax injury (AIS 3) was 1.91±1.72 in near side and 1.02±1.31 in far side ($p<0.01$).

The average MAIS at P position damage was 2.78±1.39 in near side and 2.02±1.11 in far side ($p<0.01$). In terms of ISS, the average score of ISS was 15.74±14.71 in near side and while far side was 8.11±8.39 ($p<0.01$).
For Code D of CDC damaged location intruded at the whole part of lateral side vehicle, it was also reveal that thorax injury was statically significant.
In the near side cases, 32 (68%) vehicles were passenger cars and 31 (61%) vehicles were passenger in the case of far side accidents. For near side case, 15% of near side occupants experienced more than AIS3+ and 85% was minor injury (≥AIS 2). For the far side cases, 8% of far side seated occupants suffered from AIS 3+ injury.

In terms of gender difference, there are no significant differences in injury patterns and frequency of injury.
Injury severity from different age groups, 25% of elderly front occupants (both near and far cases) suffers AIS 3+ injuries, while young adults (≥ 45 years old) only 14% and 4% for near side and far side accidents, respectively.
Near side collisions, spine, thorax and upper extremities were most frequently injured body regions. But, for far side occupants cases, head, lower extremities and thorax were mostly injured body parts.

NEAR AND FAR SIDE IMPACT CRASH TESTS

Side impact test shown in Figure 3 was conducted to evaluate the injuries and kinematic behaviors of far-side seated dummy. The test vehicle was selected from one of 2015 KNCAP side impact tested vehicle group to compare injury assessment and kinematic of near side and far side seated dummies. The far-side impact test vehicle was a small SUV which thorax and curtain airbag were equipped as standard option. In these far-side impact tests, there were two different types of testing were conducted with one ES-2 dummy was seated front passenger seat only and two ES-2 dummies were seated both in driver and passenger seats while driver side was impacted with 1,300 kg AE-MDB by 55km/h speed as shown in Figure 4. Except impact speed, all other test conditions were identical to EuroNCAP test protocol.

Figure 3. KNCAP side impact test configuration

Figure 4 KNCAP near and far side test (Test 1, 2 and 3)

RESULTS OF SIDE IMPACT TESTS

Near side dummy

As shown in Figure 5, kinematics and injury of driver (near side) was not affected by the front seated dummy except after interaction of two dummies The force and moment curves of driver's T12 were significantly influenced by far side dummy as shown in Table 1.

Figure 5 Kinematics of near side dummy (near side)

Table 1 Comparison of injuries between Test 1 and 3

Body	Injury		Criteria	Driver only Peak time)	Driver with Passenger Peak time)
Head	HIC36		1000	88(41~77ms)	81(41~73ms)
	Head G (resultant)		(80)	27(53~57ms)	27(54~57ms)
Rib	Compression (mm)	U	42	17.2(50ms)	19.4(52ms)
		M	42	18.5(50ms)	19.1(50ms)
		L	42	20.6(50ms)	20.8(50ms)
	VC(m/s)		1.0	0.12(44ms)	0.11(43ms)
Back Plate	Fx(kN)		4.0	0.58(62ms)	0.72(51ms)
	Fy(kN)		4.0	0.23(97ms)	0.18(103ms)
Spine (T12)	Fy(kN)		2.0	0.64(56ms)	1st contact: 0.76(55ms) 2nd contact: 1.0(125ms)
	Mx(Nm)		200	22.1(27ms)	1st contact: 10.4(26ms) 2nd contact: 62.3(125ms)
	My-(Nm)		200	13.7(205ms)	16.8(164ms)
Abdomen	Force(kN)		2.5	0.77(46ms)	0.96(52ms)
Pubic	Force(kN)		6	1.16(46ms)	1.64(45ms)

Near and far side dummy

Dummy seated struck side experienced the most severe damages. While the near side dummy absorbed the most impact energy and revealed higher injury, the upper body of far side dummy rotated toward to driver side seat due to reaction force. From previous researcher's studies [6, 7, 8, 9], the occupant kinematics in far-side crashes indicate that the occupant frequently comes out of the shoulder restraint and the upper body translates across the vehicle.

From a study of post mortem human specimens in far-side sled tests at 16 and 34 kph, Kent [10] found that increased engagement of the shoulder belt decreased the lateral head excursion but increased the risk of chest injury.

In this test, compare to near side dummy, the kinematic behavior of far side dummy was different as shown in Figure 6.

Figure 6 Kinematics of near and far side dummy

As shown in figures, should belt cannot restrain the occupant to prevent or minimize the upper body motion. However, the lap belt was firmly hold the pelvis area of far side dummy. This is the pivot point of motion of upper body rotation.

The injury between single dummy of near side and far side impact tests were shown in Table 2.

Table 2 Comparison of injuries between Test 1 and 2

Body	Injury		Criteria	Driver only Peak time)	Passenger only Peak time)
Head	HIC36		1000	88(41~77ms)	161(90~126ms)
	Head G (resultant)		(80)	27(53~57ms)	34(105~108ms)
Rib	Compression (mm)	U	42	17.2(50ms)	3.2(179ms)
		M	42	18.5(50ms)	13.8(188ms)
		L	42	20.6(50ms)	21.7(189ms)
	VC(m/s)		1.0	0.12(44ms)	0.08(98ms)
Back Plate	Fx(kN)		4.0	0.58(62ms)	1.68(74ms)
	Fy(kN)		4.0	0.23(97ms)	1.56(68ms)
Spine (T12)	Fy(kN)		2.0	0.64(56ms)	1.3(63ms)
	Mx(Nm)		200	22.1(27ms)	112.8(56ms)
	My-(Nm)		200	13.7(205ms)	115.1(114ms)
Abdomen	Force(kN)		2.5	0.77(46ms)	1.04(64ms)
Pubic	Force(kN)		6	1.16(46ms)	1.03(67ms)

Far side dummy

Unlike driver side, the kinematics of far side dummy is significantly influenced by whether single front seated occupant or not. As shown in Figure 7, kinematics of far side dummies were strongly affected by the existence of the front seated (driver) dummy due to interactions of dummies.

Figure 6 Kinematics of far only and far with driver

The single dummy case, far side dummy could freely rotated toward to driver seat. But, two dummy cases, the rotation of upper body of far side dummy was limited due to contact to driver dummy. Far side only case, due to direct contact to center console area, the maximum rib deflection occurred.

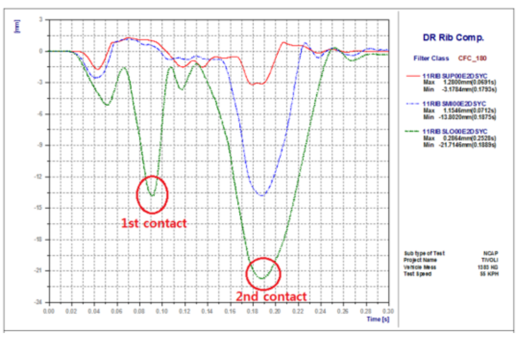

Figure 6 Rib deflections of far only case

Table 3 Comparison of far side dummy

Body	Injury		Criteria	Far side (One Dummy) Peak time)	Far side (Two Dummies) Peak time)
Head	HIC36		1000	161(90~126ms)	507(98~128ms)
	Head G (resultant)		(80)	34(105~108ms)	69(115~118ms)
Rib	Compression (mm)	U	42	3.2(179ms)	1.2(48ms)
		M	42	13.8(188ms)	1.7(42ms)
		L	42	21.7(189ms)	2.9(43ms)
	VC(m/s)		1.0	0.08(98ms)	0.00(69ms)
Back Plate	Fx(kN)		4.0	1.68(74ms)	1.32(78ms)
	Fy(kN)		4.0	1.56(68ms)	1.37(72ms)
Spine (T12)	Fy(kN)		2.0	1.3(63ms)	1.3(65ms)
	Mx(Nm)		200	112.8(56ms)	153.6(62ms)
	My-(Nm)		200	115.1(114ms)	111.5(118ms)
Abdomen	Force(kN)		2.5	1.04(64ms)	0.63(74ms)
Pubic	Force(kN)		6	1.03(67ms)	1.08(65ms)

CONCLUSIONS

From the KIDAS and side impact tests injury and kinematic motion patterns for the far side front seated occupants were examined. From the results of current works and further study, it is intension to the next step of future roadmap for KNCAP enhancement to protect far-side front seated occupants in the event of lateral collisions.

In this research works, the injury severity level for far-side front seated occupants is almost equivalent to near-side front occupant in the real accident data based on KIDAS.

From side impact test, in general, the patterns of motion of far side front seated ES-2 dummy are quite different from near side dummy as well as single far side dummy. During the impact, the seatbelt of far-side seated dummy was easily come off from dummy's shoulder. The shoulder belt cannot restrain the occupant to prevent or minimize the upper body motion. But, lap belt was firmly hold the pelvis area. This is the pivot point of motion of upper body rotation.

Side impact type accidents are the most frequent and resulting sever injury to the both driver and front seated occupants in Korea. To protect near side drivers in the event of side collisions, KNCAP evaluates with AE-MDB 55kph side impact test and oblique pole side impact test methods. However, there is no tool to protect far side occupants that will be either driver or front seated occupants.

It is required new test protocol and assessment method to adopt KNCAP program for protecting the far side seated occupants from side impact type accidents. From this study, it is recommended to far side occupant protection test should be conducted with two dummies in the existing AE-MDB 55 kph side impact crash test. It is also recommended further crash test and researches to verify benefits of adding the test protocol and detailed injury assessments. The current injury criteria and assessment values are based on the near side occupants from side collision. Also in order to global acceptance of KNCAP protocol, it is needed to further communications with other NCAP agencies

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