ANALYSIS OF SERIOUS INJURY IN CAR TO CAR ACCIDENTS TO IMPROVE OF CRASH TEST PROTOCOLS IN KNCAP

Siwoo KIM
Korea Automobile Testing & Research Institute (KATRI)
Korea, Republic of

Yohan PARK, Seungki KIM
Samsung Traffic Safety Research Institute
Korea, Republic of

Paper Number 19-0293

ABSTRACT
All over the world, there are many institutional programs used to enhance the safety of vehicles. The NCAP is a program that assesses the safety of vehicles sold by manufacturers in order to provide consumers with information on vehicle safety and to induce them to produce vehicles with enough safety. In Korea, the KNCAP has been carried out continuously since 1999. However, the fatal rate from traffic accidents per 100,000 population in 2017 is 8.1, which is above the OECD average. Therefore, it is necessary to improve various systems, but it is also necessary to improve the crash assessment protocols reflecting the actual accident. The purpose of this paper is to improve the crash test protocols of KNCAP by analyzing the status of the serious injury in case of an accident in Korea. Accident data were used for the latest three years(2015-2017) in car to car accident of domestic insurers. Raw data shows that 9,399 cases occurred due to accidents involving more than MAIS3 + of occupants' injuries. Of these, 279 cases were analyzed. In the collision type, the full width impact was the largest at 68.5%, and the small overlap and moderate at 28.3%. The low severity with 0 failure depth was 2% and the center impact was 2%. Impact angle was 51.1% for co-linear, 33.3% for left oblique angle and 15.6% for right oblique angle. In case of overlap, moderate overlap was about 47.9% and small overlap was about 17.5%. In the case of full width, crash extent3 + was 80.6%, while moderate overlap and small overlap were 36.8% and 24.3%, respectively. The collision type and impact angle compared to other country.

1. Introduction

There are many systems used to enhance the safety of motor vehicles around the world. Among them, the new car assessment program which is not legally binding is the most effective system under which the safety of motor vehicles is improved voluntarily by the vehicle manufacturers. This system is being employed in countries such as USA, Europe, Japan, China, and Korea. Recently, it has been introduced in India, ASEAN and countries in South America. The motor vehicle safety assessment system tests and evaluates the safety of motor vehicles sold by manufacturers. The system also makes the information on the motor vehicle safety public to encourage manufacturers to make safer motor vehicles. Korea has implemented the KNCAP since 1999. However, the fatalities from traffic accidents in every 100,000 people in 2017 years is 8.1, which is still higher than that of OECD average. The safety of motor vehicles has been improved, but more effective measures to reduce casualties shall be devised. For example, some safety devices may not function as intended under the accident conditions other than the test conditions. It is necessary to reflect the accident conditions in real world on the test methods. Internationally the traffic accidents pattern has been reflected on the test methods.
Euro-NCAP will replace the existing offset deformable barrier frontal impact method (40% Overlap) with a ca-to-car test method(a moving barrier, 50% overlap) for moderate overlap assessment under Roadmap 2020. In NCAP US NHTSA also announced the introduction of a car-to-car frontal oblique test using OMDB (Oblique Moving Deformable Barrier) based on NHTSA's 2015 RFC (Request for

Comments). However, in the Korean NCAP unlike those in Europe and the United States researches for the specific assessment details, protocols, and timeline have not been carried out yet for car-to-car collisions. The current domestic vehicle safety assessment is carried out under the test conditions simulating vehicle-to-fixed objects collisions and vehicle-to-pedestrian collisions among real world accidents.

Since the introduction of KNCAP the safety of vehicles in the domestic market has been continuously improved so that vehicles with high safety ratings have the effect of reducing the injury severities and fatalities. However, it is suspected that the safety performance may not be not fully realized due to the failure of some safety devices in the real accident conditions other than the assessment conditions, These discrepancies between assessment ratings and real world performances are posing a potential threat to the credibility of the safety ratings.

Therefore, it is necessary to take a careful consideration and improvement measures for vehicle safety in case of car-to-car accidents with high frequency in addition to car-to-pedestrians accidents and single vehicle accidents among real world vehicle accidents. In particular, considering the fact that car-to-car accidents are more frequent than single vehicle accidents from casualties' point of view among the victims of traffic accidents, it is necessary to investigate that the occupant protection in car-to-car accidents is equivalent to that in single vehicle accidents through the current assessment program. In this study, based on the analysis of the main accident type and injury characteristics of fatalities and severe injuries excerpted from vehicle accidents database, the improvement of motor vehicle assessment program will be proposed through feasibility study on car-to-car crash tests.

2. Contents and Methods of Investigation

For the in-depth analysis of the injury characteristics of severely injured occupants from car-to-car accidents, the injury characteristics were analyzed based on accident data from insurance companies database between from 2015 and 2017(3 years) met the following conditions. Among frontal collisions and side impacts involving only two vehicles were selected and the ones with more than two vehicles involved were excluded. In the cases investigated, the accidents resulted in fatal or injured occupants with AIS 3 or higher, who had fastened their safety belts at the time of accidents. In addition, damage on vehicles due to collision has to be identifiable in the accidents involving only passenger vehicles. Analysis data were in the following Table 1.

Table 1. Overview of Analysis Data

Category	Item	Explanatory Note
Scope	·Collision Type	·Frontal collision
	·Occupant	·Severely Injured Occupants with AIS 3 or higher
	·Vehicle Classification	·Passenger vehicle-to-Passenger vehicle
Period	·Reported Period	·1. 1. 2015 ~ 31. 12. 2017
Contents	·Analysis of Frequent Accident Types → Vehicle Deformation → Collision Angle and Degree of Overlap	· 279 cases in Frontal collision
	·Characteristics of Severely Injured Occupants → Distribution of Severe Injury Areas → Injury Types in Severe Injury Areas	· 311 severely injured occupants in frontal collision

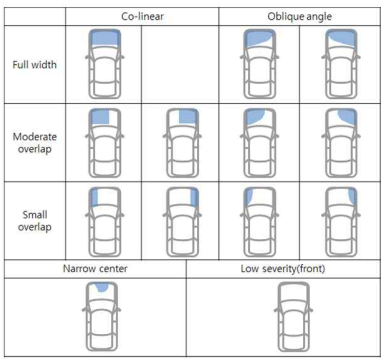

Figure 1. Collision Deformation Classification

The types of damage and the angles of collisions were classified by the Collision Deformation Classification (CDC) as the Figure 1, and the types of collisions and the angles of collisions were categorized based on detailed damaged areas and extent of damage.

The types of damage from frontal collision were classified into 5 types as Figure 2. A full frontal collision case is the case when both left and right side member structures, including the center, of a vehicle were destroyed. A moderate overlap frontal collision case is the case when either left or right

side member of a vehicle was damaged and also the center of a vehicle was damaged. A small overlap frontal collision case is the case when only either left or right side member of a vehicle was damaged, but the center of a vehicle was not damaged. A narrow center frontal collision case is the case when both left and right side member structures of a vehicle were not destroyed, but the center of a vehicle was destroyed. A frontal collision case with low severity is the case where the extent of damage is zero regardless of the location of damage.
The degree of overlap in a partial frontal collision was defined by the step of 20% overlap after the front part of a damaged vehicle was divided into 5 parts vertically and laterally. The degree of overlap in the partial frontal collision was set as follows according to the point of the damaged part.

20% Overlap : point 2~3 or 4~5 damaged
40% Overlap : point 1~3, 2~4, 3~5 or 4~6 damaged
60% Overlap : point 1~4 or 3~6 damaged

the degree of small overlap was defined as follows.
10% Overlap: only point 1 or 6 damaged
20% Overlap: only point 1~2 or 5~6 damaged

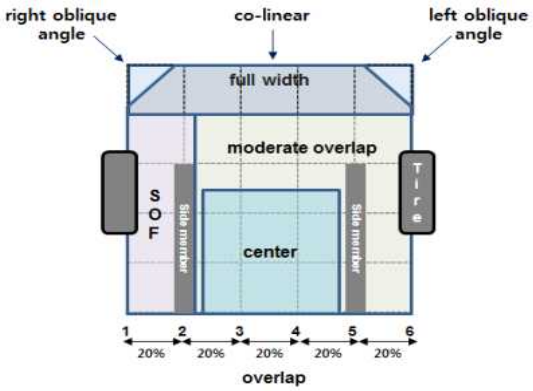

Figure 2. Types of Frontal Collision and Definition of Overlap

The injury characteristics analysis of severely injured occupants was carried out by the gender and occupied seat of an occupant according to the type of deformation, collision angle and degree of overlap of an accident vehicle as follows. The type of deformation, collision angle and degree of overlap was examined according to the criteria described previously. During the analysis, severely injured occupants resulted from a narrow center frontal collision and a frontal collision case with low severity were excluded from the analysis. For injury area analysis, multiple injuries in various areas of single severely injured occupant were repeatedly counted in consideration of multiple compound injuries. For example, if one severely injured occupant sustained two injuries in the head, two injuries were counted as two.

3. Results of Analysis

3-1. Analysis of Deformation Characteristics of Accident Vehicles with High Frequency and Severely Injured Occupants

The type of full frontal damage(Full width) accounted for 68.5% and the type of partial frontal damage(Moderate overlap + Small overlap) accounted for 28.3% as Table 2. In the type of partial frontal damage, a similar share was observed between two sub categories.

Table 2. Types of Deformation in case of Frontal Collisions with High Frequency (unit: No. of vehicles, %)

Types of Deformation		Frequency(%)
Full Frontal (Full width)		191 (68.5)
Partial Frontal	Moderate overlap	38 (13.6)
	Small overlap	41 (14.7)
Narrow Center Frontal Collision		4 (1.4)
Frontal Collision with Low Severity		5 (1.8)
Total		279 (100.0)

In terms of collision angles, as Table 3, the type of frontal collision in the perpendicular direction accounted for 51%, the type of frontal collisions in the left oblique direction accounted for 33% and the type of frontal collisions in the right oblique direction accounted for 16%.

Out of frontal collisions in the perpendicular direction, the type of full frontal collisions accounted for 64.5%, the type of partial frontal collisions accounted for 15.2%, and the type of small overlap frontal collisions accounted for 20.2%. For the type of frontal collisions in the left oblique direction, the type of full frontal collisions accounted for 78.9%, the type of partial frontal collisions accounted for 12.2%, and the type of small overlap frontal collisions accounted for 8.9%. For the type of frontal collisions in the right oblique direction, the type of full frontal collisions accounted for 73.8%, the type of partial frontal collisions accounted for 14.3%, and the type of small overlap frontal collisions accounted for 11.9%.

Table 3. Collision Angles in case of Frontal Collisions with High Frequency (unit: No. of vehicles, %)

Collision Angle	Deformation Type	Damage Area	Frequency(%)	Total
Co-liner Direction	Full width	Full with	89(64.5)	138 (51.1)
	Moderate	Left side	14(10.1)	
		Right side	7(5.1)	
	Small overlap	Left side	14(10.1)	
		Right side	14(10.1)	
Sum			138(100.0)	
Left oblique Direction	Full width	Left side	71(78.9)	90 (33.3)
	Moderate	Left side	11(12.2)	
	Small overlap	Left side	8(8.9)	
Sum			90(100.0)	
Right oblique Direction	Full width	Right side	31(73.8)	42 (15.6)
	Moderate	Right side	6(14.3)	
	Small overlap	Right side	5(11.9)	
Sum			42(100.0)	
Total				270(100.0)

Note) Total No. is not included the Narrow center and Low severity cases

As comparison of the degrees of overlap in partial frontal collisions shown in the Table 4, the average degree of overlap in the partial frontal collisions(moderate overlap) was 47.9%, and the portions of 40% overlap and 60% overlap were similar to each other. The average degree of in the partial frontal collisions(small overlap) was 17.5%, and 20% overlap accounted for the largest portion of 75.6%.

Table 4. Degree of Overlap in case of Partial Frontal Collisions with High Frequency (unit: No. of vehicles, %)

Degree of Overlap		Frequency(%)	Average Degree of Overlap
Moderate overlap	20% overlap	3(7.9)	47.9%
	40% overlap	17(44.7)	
	60% overlap	18(47.4)	
	Sum	38(100.0)	
Small overlap	10% overlap	10(24.4)	17.5%
	20% overlap	31(75.6)	
	Sum	41(100.0)	

Table 5. shows the results of comparison and analysis of the extent of damage according to the types of damage. Most full frontal collisions resulted in Extent of Damage 3 or higher, and most partial frontal collisions resulted in Extent of Damage 3 or less. In case of full frontal collisions, Extent of Damage 3 or higher accounted for 80.6%, while in case of partial frontal collisions Extent of Damage 3 or less accounted for the majority.

Table 5. Types of Deformation in case of Frontal Collisions with High Frequency(units : No. of vehicles, %)

Types of Deformation		Extent of Damage					Total
		1	2	3	4	5	
Full width		7 (3.7)	30 (15.7)	82 (42.9)	66 (34.6)	6 (3.1)	191 (100)
Partial	Moderate overlap	12 (31.6)	12 (31.6)	10 (26.3)	3 (7.9)	1 (2.6)	38 (100)
	Small overlap	20 (48.8)	11 (26.8)	5 (12.2)	5 (12.2)	0 (0)	41 (100)
Narrow center		0 (0)	3 (75.0)	1 (25.0)	0 (0)	0 (0)	4 (100)

Note) frontal collision with low severity : EXTENT 0 = 5 units

3-2 Injury Analysis of Severely Injured Occupants

The analysis of distribution of severely injured occupants according to the gender and seat of occupant showed that the majority of male were drivers and the majority of female were passengers. In the case of severely injured male occupants, 74% of occupants in the driver's seat and 14% in the passenger seats account for 91.7% of the occupants in the first row seats (driver's seat + passenger's seat). In the case of severely injured female occupants, 78.2% of severely injured female occupants were seated in the first row seat (driver's seat + passenger's seat), but the occupancy rate of severely injured female occupants in the second row seat (18.3%) was higher than that of the male. (See the Table 6.)

Table 6. Distribution of Severely Injured Occupants according to the Seat/Gender in case of Frontal Collisions with High Frequency(units : No. of injuries, %)

Gender	1st row Seat		2nd row Seat			Total
	Driver'	Passenger'	behind Driver	Center	behind Passenger	
Male	125 (74.0)	30 (17.8)	1 (0.6)	1 (0.6)	10 (5.9)	169 (100.0)
Female	63 (44.4)	48 (33.8)	10 (7.0)	1 (0.7)	15 (10.6)	142 (100.0)
Total	188 (60.5)	78 (25.1)	11 (3.5)	2 (0.6)	25 (8.0)	311 (100.0)

Table 7. shows the analysis of distribution of severely injured occupants according to the age of occupant. Severely injured adult occupants were drivers who accounted for 76.9%. Severely injured

adult female drivers accounted for 50.9%, while severely injured adult female passengers accounted for 46.6%. There is little difference. For elderly people, the majority of injured occupants were male drivers, while the majority of old female occupants were seated in the passenger seat in the 1st and 2nd rows. For elderly female occupants, passengers next to the driver accounted for 31.8%. Female occupants in the passenger seat in the 1st and 2nd rows accounted for 40.9%.

Table 7. Distribution of Severely Injured Occupants according to the Seat/Age of Occupant in case of Frontal Collisions with High Frequency(units : No. of injuries, %)

Age		1st row Seat		2nd row Seat			Total
		Driver'	Passenger'	behind Driver	Center	behind Passenger‘	
Male	Child	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	2 (66.7)	3 (100.0)
	Adult	110 (76.9)	22 (15.4)	1 (0.7)	1 (0.7)	7 (4.9)	143 (100.0)
	Elderly	15 (65.2)	7 (30.4)	0 (0.0)	0 (0.0)	1 (4.3)	23 (100.0)
Female	Child	0 (0.0)	1 (25.0)	1 (25.0)	1 (25.0)	1 (25.0)	4 (100.0)
	Adult	59 (50.9)	40 (34.5)	5 (4.3)	0 (0.0)	9 (7.8)	116 (100.0)
	Elderly	4 (18.2)	7 (31.8)	4 (18.2)	0 (0.0)	5 (22.7)	22 (100.0)
Total		188 (60.5)	78 (25.1)	11 (3.5)	2 (0.6)	25 (8.0)	311 (100.0)

Table 8. shows the analysis of distribution of severely injured occupants according to types of deformation in frontal collisions. In case of a full frontal collision, chest injuries were most frequent, followed by low extremity injuries and head injuries. In case of a moderate frontal collision, low extremity injuries were most frequent, followed by chest injuries and upper extremity injuries. In case of a small overlap frontal collision, upper extremity injuries were most frequent, follwed by low extremity injuries and chest injuries. As the area of the damaged part if an accident vehicle changes, the behavior of occupants may also change. Due to the different behavior frequently injured areas in occupants shows different tendency. The chest injuries became less and less frequent from full frontal collision to partial frontal collision, which is considered to be correlated with the reduction in damaged area. In case of upper/lower extremities, the rate of injury increased in a full frontal collision compared with a partial frontal collision because the safety belt could not effectively restrain an occupant due to yawing in a frontal collision.

Table 8. Severely Injured Area according to Types of Deformation in case of Frontal Collisions with High Frequency(units : No. of injuries, %)

Deformation Type	head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Full width	43 (14.4)	39 (13.1)	5 (1.7)	115 (38.6)	2 (0.7)	30 (10.1)	63 (21.1)	1 (0.3)	298 (100.0)
Moderate overlap	6 (8.8)	8 (11.8)	0 (0.0)	19 (27.9)	0 (0.0)	11 (16.2)	22 (32.4)	2 (2.9)	68 (100.0)
Small overlap	4 (7.0)	10 (17.5)	2 (3.5)	11 (19.3)	0 (0.0)	17 (29.8)	13 (22.8)	0 (0.0)	57 (100.0)

The analysis of distribution of severely injured area of occupants according to the collision angle in frontal collisions shows that in case of a full frontal collision, the differences among the shares of

injured areas were little regardless of collision angles, while the shares of injured areas tend to differ greatly depending on collision angles in case of a partial frontal collision as Table 9.
In case of a moderate overlap frontal collision, lower extremity injuries in frontal collisions in the left oblique direction decreased by 12% compared with that in frontal collisions in the perpendicular direction; chest injuries increased by 13%; head injuries increased by 8%.
In case of a small overlap frontal collision, lower extremity injuries in frontal collisions in the left oblique direction decreased by 11% compared with that in frontal collisions in the perpendicular direction; chest injuries increased by 10%; head injuries increased by 5%.

Table 9. Distribution of Severely Injured Area of Occupants according to the Collision Angle in case of Frontal Collisions with High Frequency(units : No. of injuries, %)

Collision Angle		head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Full width	perpendicular	22 (15.9)	17 (12.3)	1 (0.7)	49 (35.5)	0 (0.0)	15 (10.9)	33 (23.9)	1 (0.7)	138 (100.0)
	oblique	21 (13.1)	22 (13.8)	4 (2.5)	66 (41.3)	2 (1.3)	15 (9.4)	30 (18.8)	0 (0.0)	160 (100.0)
Moderate overlap	perpendicular	2 (5.4)	5 (13.5)	0 (0.0)	8 (21.6)	0 (0.0)	6 (16.2)	14 (37.8)	2 (5.4)	37 (100.0)
	oblique	4 (12.9)	3 (9.7)	0 (0.0)	11 (35.5)	0 (0.0)	5 (16.1)	8 (25.8)	0 (0.0)	31 (100.0)
Small overlap	perpendicular	2 (5.3)	7 (18.4)	1 (2.6)	6 (15.8)	0 (0.0)	11 (28.9)	11 (28.9)	0 (0.0)	38 (100.0)
	oblique	2 (10.5)	3 (15.8)	1 (5.3)	5 (26.3)	0 (0.0)	6 (31.6)	2 (10.5)	0 (0.0)	19 (100.0)

The analysis of distribution of severely injured area of occupants according to the degree of overlap in frontal collisions shows that upper/lower extremity injuries increased as the degree of overlap decreased.(See the Table 10) In case of a moderate overlap frontal collision, neck injuries decreased and upper extremity injuries increased from 6.3% to 29.0% as the degree of overlap decreased. In case of a small overlap frontal collision, neck injuries decreased from 22% to 6% and lower extremity injuries increased from 12% to 50% as the degree of overlap decreased.

Table 10. Distribution of severely Injured Area of Occupants according to the Degree of Overlap in case of Frontal Collisions with High Frequency(units : No. of injuries, %)

Degree of Overlap		head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Moderate overlap	20%	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	5 (100.0)
	40%	4 (12.9)	1 (3.2)	0 (0.0)	9 (29.0)	0 (0.0)	9 (29.0)	8 (25.8)	0 (0.0)	31 (100.0)
	60%	2 (6.3)	7 (21.9)	0 (0.0)	10 (31.3)	0 (0.0)	2 (6.3)	9 (28.1)	2 (6.3)	32 (100.0)
Small overlap	10%	1 (6.3)	1 (6.3)	0 (0.0)	2 (12.5)	0 (0.0)	4 (25.0)	8 (50.0)	0 (0.0)	16 (100.0)
	20%	3 (7.3)	9 (22.0)	2 (4.9)	9 (22.0)	0 (0.0)	13 (31.7)	5 (12.2)	0 (0.0)	41 (100.0)

As Table 11, the analysis of distribution of severely injured area of occupants according to the seat/gender in frontal collisions shows that chest injuries were most frequent in the occupants in the 1st row seats while head injuries were most frequent in the occupants in the 2nd row seats. In case of drivers, the distribution of severely injured areas in male and female drivers were similar to each other. Chest injuries were most frequent, followed by lower extremity injuries and neck injuries. Head

injuries were least frequent. For male drivers, chest injuries(37.4%) were most frequent, followed by lower extremity injuries(23.6%) and neck injuries(17.1%). Head injuries(13.0%) were least frequent. For female drivers, chest injuries(39.3%) were most frequent, followed by lower extremity injuries(19.6%) and neck injuries(14.3%). Head injuries(12.5%) were least frequent. In case of passengers next to drivers, chest injuries were most frequent in male and female passengers. For male passengers, head injuries were the next most frequent, while for female passengers, lower extremity injuries were the next most frequent. For male passengers, chest injuries(46.5%) were most frequent, followed by head injuries(18.2%) and upper/lower extremity injuries(15.2). For female passengers, chest injuries(45%) were most frequent, followed by lower extremity injuries(24%), upper extremity injuries(21%) and head injuries(4%). Head injuries were least frequent. In case of occupants in the 2nd row, head injuries were most frequent in male and female passengers. Chest injuries for male passengers and lower extremity injuries for female passengers were next highest. For male passengers, head(35.7%) and chest injuries(35.7%) were most frequent, followed by neck injuries(21.4%). For female passengers, head injuries(31.8%) and lower extremity injuries(31.8%) were most frequent, followed by chest injuries(22.7%).

Table 11. Distribution of Severely Injured Area of Occupants according to the Occupied Seat in case of Full Frontal Collisions(Full Width) with High Frequency(units : No. of injuries, %)

Occupied Seat		head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Male	Driver's	16 (13.0)	21 (17.1)	2 (1.6)	46 (37.4)	1 (0.8)	8 (6.5)	29 (23.6)	0 (0.0)	123 (100.0)
	Passenger's	6 (18.2)	2 (6.1)	0 (0.0)	15 (45.5)	0 (0.0)	5 (15.2)	5 (15.2)	0 (0.0)	33 (100.0)
	2nd Row	5 (35.7)	3 (21.4)	1 (7.1)	5 (35.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	14 (100.0)
Female	Driver's	7 (12.5)	8 (14.3)	1 (1.8)	22 (39.3)	0 (0.0)	6 (10.7)	11 (19.6)	1 (1.8)	56 (100.0)
	Passenger's	2 (4.3)	3 (6.4)	0 (0.0)	21 (44.7)	0 (0.0)	10 (21.3)	11 (23.4)	0 (0.0)	47 (100.0)
	2nd Row	7 (31.8)	2 (9.1)	0 (0.0)	5 (22.7)	1 (4.5)	0 (0.0)	7 (31.8)	0 (0.0)	22 (100.0)

Table 12. Distribution of Severely Injured Area of Occupants according to the Occupied Seat in case of Moderate Frontal Collisions with High Frequency (units : No. of injuries, %)

Occupied Seat		head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Male	Driver's	1 (3.6)	3 (10.7)	0 (0.0)	8 (28.6)	0 (0.0)	3 (10.7)	11 (39.3)	2 (7.1)	28 (100.0)
	Passenger's	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (75.0)	0 (0.0)	4 (100.0)
	2nd Row	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
Female	Driver's	1 (9.1)	1 (9.1)	0 (0.0)	3 (27.3)	0 (0.0)	3 (27.3)	3 (27.3)	0 (0.0)	11 (100.0)
	Passenger's	1 (12.5)	2 (25.0)	0 (0.0)	2 (25.0)	0 (0.0)	2 (25.0)	1 (12.5)	0 (0.0)	8 (100.0)
	2nd Row	1 (8.3)	1 (8.3)	0 (0.0)	4 (33.3)	0 (0.0)	2 (16.7)	4 (33.3)	0 (0.0)	12 (100.0)

The distribution of severely injured area of occupants according to the seat/gender in moderate overlap frontal collisions was analyzed. For the occupants in the 1st row seats, lower extremity injuries for male passengers

and chest and upper extremity injuries for female passengers were most frequent. For female occupants in the 2nd row seats, chest injuries and lower extremity injuries were most frequent. (See the Table 12)
Lower extremity injuries were most frequent for both male and female drivers. For passengers next to drivers, lower extremity injuries were most frequent for male passengers and chest injuries, neck injuries and upper extremity injuries for female passengers were most frequent.
Table 13 shows that the analysis of distribution of severely injured area of occupants according to the seat/gender in small overlap frontal collisions were that upper extremity injuries for male passengers and lower extremity injuries for female passengers were most frequent among the occupants in the 1st row seats.
In case of male drivers, upper extremity injuries were most frequent, followed by lower extremity injuries and chest injuries. In case of female drivers, neck injuries were most frequent, followed by lower extremity injuries and chest injuries.

Table 13. Distribution of Severely Injured Area of Occupants according to the Occupied Seat in case of Small Overlap Frontal Collisions(Full Width) with High Frequency(units : No. of injuries, %)

Occupied Seat		head	neck	back-spine	chest	abdominal	upper extremity	lower extremity	full body	Total
Male	Driver's	2 (8.3)	3 (12.5)	1 (4.2)	4 (16.7)	0 (0.0)	9 (37.5)	5 (20.8)	0 (0.0)	24 (100.0)
	Passenger's	0 (0.0)	1 (25.0)	0 (0.0)	1 (25.0)	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)	4 (100.0)
	2nd Row	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)
Female	Driver's	1 (6.3)	5 (31.3)	1 (6.3)	3 (18.8)	0 (0.0)	2 (12.5)	4 (25.0)	0 (0.0)	16 (100.0)
	Passenger's	0 (0.0)	1 (14.3)	0 (0.0)	1 (14.3)	0 (0.0)	1 (14.3)	4 (57.1)	0 (0.0)	7 (100.0)
	2nd Row	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (66.7)	0 (0.0)	0 (0.0)	3 (100.0)

4. Discussion

It is time for a new car assessment program on which multiple vehicle accidents patterns are reflected to encourage manufacturer to improve vehicle safety through assessing vehicle safety in the car-to-car accidents which account for the majority among traffic accidents. It is expected that vehicle safety will be assessed in the event of car-to-car collisions under both Euro-NCAP and US NCAP. It is required to develop measures to strengthen the competitiveness of domestic automobile industry, in addition to enhance the domestic traffic safety index.
In consideration of the high fatality and severe injury rate in partial frontal collisions, the damage area/collision angle/speed of an assessed vehicle should be reviewed when developing a scenario for a new car assessment program on which the characteristics of real world vehicle accidents in Korea will be reflected. Specially the high severe injury rate in partial frontal collisions should be noted even though the extent of damage in a partial frontal collisions is lower than that of a full frontal collision. Because fatalities and severely injured occupants in the same occupied seat are quite different in the genders, various type of test dummies and occupied seats may be considered in a new car assessment program on which the characteristics of real world vehicle accidents in Korea will be reflected.
In addition, in consideration of major injured areas and injury types of severely injured occupants resulted from car-to-car accidents were chest fractures and upper/lower extremity fractures, It is deem to be necessary to establish the evaluation criteria to reduce these kinds of injuries in assessing impacts to the parts of a test dummy corresponding to the frequently injured areas of occupants. It is possible to minimize the discrepancy between the assessment and the actual accident injury reduction

effect by supplementing the additional parts in addition to the parts of a test dummy used in the current new car assessment program in consideration of the injury characteristics of severely injured occupants resulted from real world car-to-car accidents.

5. Conclusion

The following conclusions were drawn from the analysis of characteristics of the severely injured occupants based on the database of domestic insurance companies.
Partial frontal collisions and side impacts resulted in severely injured occupants even though the extent of damage was low. For partial frontal collisions, the type of 60% off-set collision co-linearly on the left(driver side) was most frequent. In this type of collisions male drivers and female passengers were severely injured with high frequency regardless of age. Chest injuries were most frequent in the severely injured occupants.
Based on the results of the analysis of the car-to-car accidents in Korea, it is necessary to further study the standardization of the collision assessment technology which the real world accidents patterns can be reflected in order to secure the collision safety additionally in the new car assessment program.

REFERENCES

[1] Injury distribution, The Guarantee of Automobile Accident Compensation Act in KOREA,

[2] Traffic Accident Analysis System Datebase, 2008~2017, http://tass.korad.or.kr

[3] ANDERS LIE, CLAES TINGVALL, How Do Euro NCAP Results Correlate with Real-Life Injury Risks? A Paired Comparison Study of Car-to-Car Crashes, Traffic Injury Prevention, 3:288-293, 2002

[4] Kullgren A, Lie A , Tingvall C.Comparison Between Euro NCAP Test Results and Real-World Crash Data. Traffic Injury Prevention, 11:587-593, 2010

[5] Dennis R. Durbin, Jessica S.Jermakian, Michael J Kallan, Anne T. McCartt, Kristy B.Arbogast, Mark R.Zonfrillo, Rachel K. Myers, Rear seat safety: variation in protection by occupant, crash and vehicle characteristics, IIHS, 2015

[6] Hampton Gabler, Kennerly Digges, Brian N. Filders, Laurie Sparke, Side impact injury risk for belted far side passenger vehicle occupants(Hampton et al., 2005)

[7] Sandner et al, EURO NCAP FRONTAL IMPACT WORKING GROUP REPORT, 25th ESV conference proceedings, paper number 17-0205

[8] Saeed Barbat et al, ANALYSIS OF THE PROPOSED FRONTAL OBLIQUE CRASH TEST, 25th ESV conference proceedings, paper number 17-0130

[9] Matthew L. B., David S. Z., IMPACT AND INJURY PATTERNS IN FRONTAL CRASHES OF VEHICLES WITH GOOD RATINGS FOR FRONTAL CRASH PROTECTION, 21th ESV conference proceedings, paper number 09-0257

[10] National Highway Traffic Safety Administration, Federal Register, Vol. 80, No. 241, 2015

[11] National Highway Traffic Safety Administration, NASS Analysis in Support Of NHTSA's Frontal Small Overlap Program, DOT HS 811 522, 2015