# Investigation for New Side Impact Test Procedures in Japan

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## ABSTRACT

Side impact regulations have been introduced in many countries to improve occupant protection in side collisions. As a result, car structures have been improved significantly. However, the number of fatalities and serious injuries in side collisions is still large. To understand the causes of these injuries and to identify their potential countermeasures, accident analyses of side collisions were newly conducted.

From the accident data analysis, it was shown that the contacts with the head and chest during side crashes are still a major cause of serious injuries and death. The impact vehicle type affected the injured body regions of the occupant in the struck vehicle, and the chest was frequently injured in the struck car when impacted by an 1BOX type vehicle. Occupant seating postures were surveyed in vehicles on the roads, and it was found that from a side view that the head location of 50% of the drivers was in line or overlapped with the vehicle's B-pillar. This observation suggests that in side collisions head injuries may occur frequently due to contacts with the B-pillar.

A series of side impact tests were conducted to examine test procedures that would be beneficial for improving occupant protection. When the 1BOX was a striking vehicle, the chest deflection of the ES-2 dummy was large. The crash tests also included car-to-car crash tests in which either (1) both cars are moving or (2) one car is stationary, i.e., an ECE R95 test. The injury measures of the ES-2 dummy were substantially smaller if the struck car was moving.

The tests also were conducted for an occupant seating position where the head would make contact with the B-pillar. To investigate the effectiveness of curtain side airbags for head protection in car-to-car crashes, these test were conducted for struck cars with and without a curtain side airbag. It was demonstrated that the curtain side airbag was effective for reducing the number of head injuries in car-to-car crashes.

## INTRODUCTION

Though the number of vehicle accidents is decreasing recently, in 2008 it was 760,000 or more, and the number of injuries was 940,000 or more. Considering this traffic accident situation, regulations for occupant protection including the side impact protection [1] have been introduced in Japan. Additionally, The Japan New Car Assessment Program (JNCAP) conducts safety evaluation of new cars.

In traffic accidents in Japan, intersection collisions and rear-end collisions account for about 60% when classified by collision configuration and vehicle-to-vehicle collisions account for 80% or more when classified by crash objects. In fatal and serious injuries to drivers, vehicle-to-vehicle collisions account for a large proportion. In vehicle-to-vehicle side collisions, since the crash configurations are widely varied (such as a large array of impact velocities and angles), an investigation of representative crash test procedures is necessary in order to effectively reduce the number of fatal and serious injuries in side crashes, and to protect the occupants most frequently seriously injured body regions.

In this study, building on the bases of our past studies [2][3][4][5][6][7], side accident analyses, field surveys of occupant postures, and car-to-car side impact tests were conducted. Based on the results of these studies, the trend for a representative side impact test procedure for the future was investigated. In accident analyses, the general trend of side collisions were investigated based on the Institute for Traffic Accident Research and Data Analysis (ITARDA) global accident data for 3 years (2006-2008). In the occupant posture investigation, the relative positions of the head of the driver and passenger with respect to the B-pillar were examined to understand the potential of injury

causation by the B-pillar in side collisions. Several car-to-car crash tests were conducted to investigate potential side impact test procedures for the future. Taking the results of seating posture investigation into account, the crash tests were conducted to understand the effects of curtain side airbag (CSAB) and side air bag (SAB) which were installed recently on many cars.

## STUDY ON SIDE IMPACT ACCIDENT IN JAPAN

In this study, the accident analyses in Japan were examined using the police data. From the data, in 2008, the number of traffic accidents in Japan was 766,147, the number of injuries was 950,659, and the number of fatalities (i.e., fatalities within 30 days after an accident) was 6,023.

### General Trend of Side Impact Accidents

The number of traffic accidents in which occupants of four-wheel vehicles were involved was 1.4 million from 2005 to 2007. Figure 1 shows the crash configurations as classified by impact locations. A large portion of the total accidents were rear-end collisions. In the fatal and serious accidents, the percentage of frontal collisions was large. Side collisions occupy about 20% of fatal accidents as well as fatal and serious accidents. These findings indicate that, when considering the potential safety benefit of a crash configuration, the side collision is next in importance to the frontal collision, of which the risk of fatal and serious injury to occupants was high.

The fatal and serious injuries of front seat occupants were examined for side collisions which included vehicle-to-vehicle intersection collisions and single vehicle collisions. Multiple collisions were excluded. Figure 2 shows the percentage of striking vehicle and object types by seat position (struck-side or non struck-side) of the front seat occupants in the struck vehicle. Sixty percent of the fatal and serious injuries in side collisions are on the struck side occupants, and 40% are the non-struck side occupants. Eighty percent of the striking objects were vehicles, which account for the largest source of striking objects. Among these, the mini passenger cars and passenger cars account for 60%. Narrow objects (e.g., signals, telephone poles, and road signs) account for 6% or less.

Figure 3 shows the injured body regions of the occupants by striking objects. When struck by an 1BOX or SUV, and a Large vehicle or Truck, the percentage of head and chest injuries was large, whereas that of neck injury decreases. When struck by a pole, the percentage of head injuries is large. The percentage of abdomen injuries is lowest, irrespective of striking objects.

Figure 4 shows the relation between injured body regions to the struck-side occupants and injury causes. The door and window account for the largest percentage of injury causes. Seats account for 60% of the injury causes for the neck. The pillars, which have probably high injury potentials in the passenger compartment, account for only small percentages of injury causes. To understand the injury causes in side impact collisions in more detail, it is necessary to examine the injury causes using in-depth accident data.

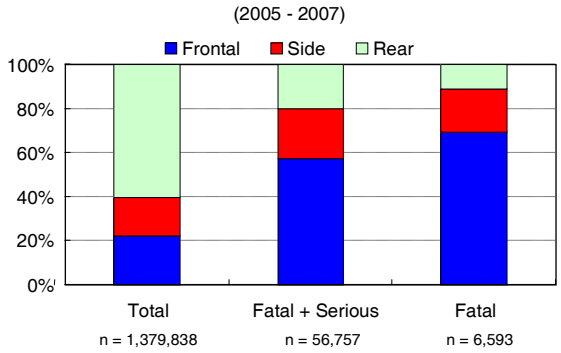



**Figure 1 Impact configuration of vehicle accidents**

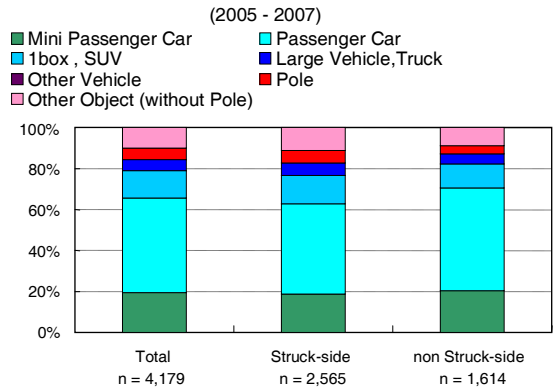



**Figure 2 Type of striking vehicle and object involved in side impact accidents (fatal and serious injuries).**

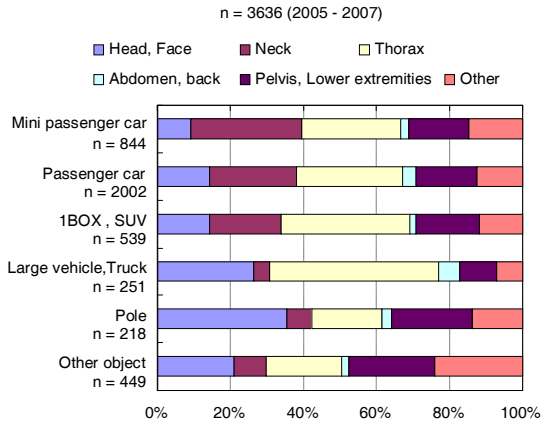



**Figure 3 Injured body regions for fatal and serious injuries in side impact accidents by striking object.**

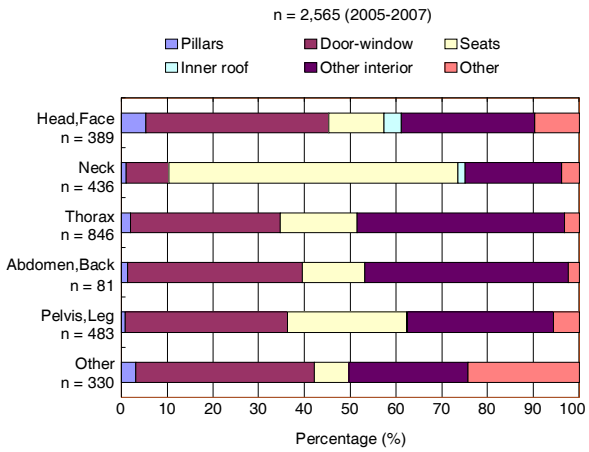



**Figure 4 Contact parts for injuries in side impact accidents (struck-side occupant)**

## INVESTIGATION OF RIDING POSTURE POSITION

The postures of the driver and front passenger in the real-world were surveyed in order to provide a basis to predict injury causes of the car interior in side impact accidents. The pictures of the position of a front seat occupant were recorded by a video camera from a side view of the vehicle, and the occupant head's position was observed. From the accident analyses, the head was a frequently injured body region in side impact accidents. Therefore, the percentage of occupants whose head location overlapped with the vehicle's B-pillar was examined. By analyzing the results, the conditions for which occupant protection devices effectively work (i.e., the area to be covered by the occupant protection device) also could be estimated.

### Investigation on Driver and Passengers Seating Position in Real World

Side views of vehicles traveling in both directions of the road near an intersection were filmed with a video recorder. From the side view of the occupants, the percentage of the occupants whose head overlapped with the B-pillar was examined. The head positions of drivers (right side) and front passengers (left side) were surveyed. The surveyed vehicles were passenger cars (sedan, wagon, and 1BOX) and mini passenger cars. The large vehicles such as truck and bus, and 2-door cars were excluded from the survey. In total, 377 cars were surveyed from driver side, and 256 cars were surveyed from the front passenger side. However, note that only 45 front passengers were examined since front passenger seating frequency was observed to be 18%. Figure 5 shows the criterion used to evaluate whether the head overlapped the B-pillar. Even if only a part of the head overlapped with the B-pillar, it was defined as head/B-pillar overlap.

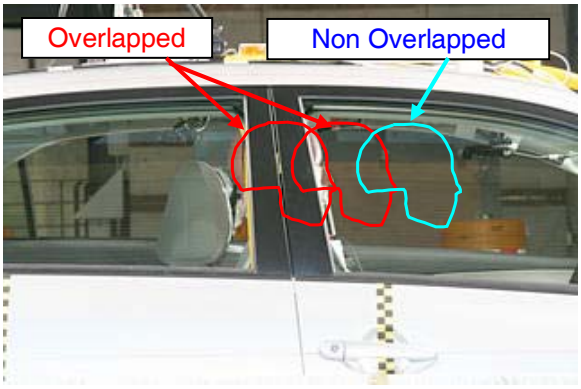



**Figure 5 The criterion of judgment for the head overlapping B-pillar**

Figure 6 shows the percentages of head/B-pillar overlap for the driver and front passenger. Fifty percent of drivers and 70% of front passengers were determined to have head/B-pillar overlap. The percentage of front passengers was large probably because front passengers have the freedom to change their seat positions, whereas the drive must adjust the seat to accommodate reaching the steering wheel and floor pedals. Figure 7 shows the percentages of the head/B-pillar overlap of drivers by male and female. The percentage of head/B-pillar overlap for female was about half of that for male. It is likely that the body size of the driver affects the overlap percentages.

Figure 8 shows the percentage of the head/B-pillar overlap of the driver by car type. The percentage of head/B-pillar overlap for 1BOX was larger than that for the sedan and wagon. This is probably because the B-pillar of the 1BOX is located more forward as compared to the sedan due to its vehicle design.

Based on the survey, it was found that 50% of the driver heads overlapped the B-pillar. The male has a high frequency of head and B-pillar overlap. The driver head overlaps more frequently with the B-pillar of 1BOX as compared to that for the sedan. Accordingly, it is predicted that the head is likely to contact the B-pillar during side crashes, and thereby lead to head injuries.

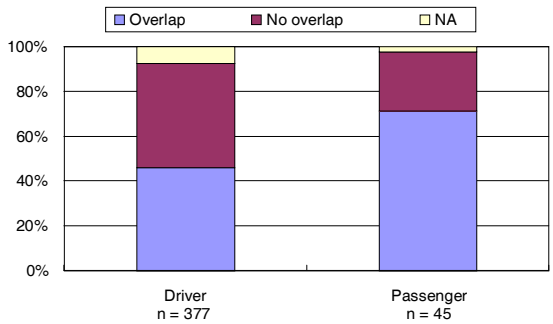



**Figure 6 Seat location for the head and B-pillar overlapped.**

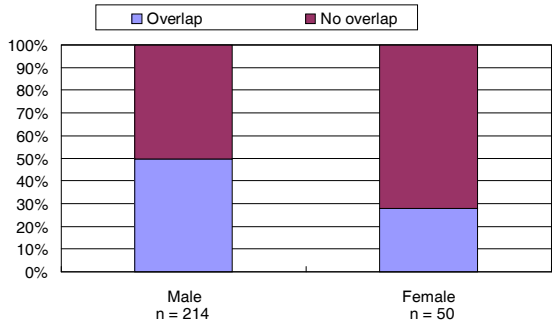



**Figure 7 Gender for the head and B-pillar overlapped (Driver).**

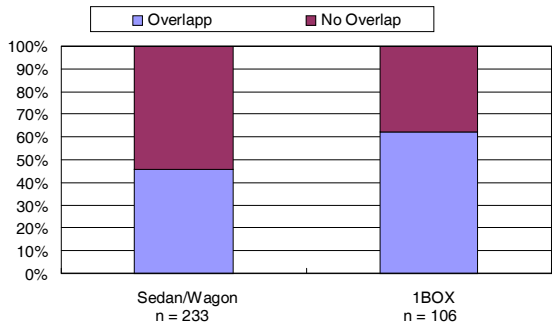



**Figure 8 Type of vehicle for the head and B-pillar overlapped (Driver).**

## FULL-SCALE SIDE IMPACT TEST

### Test Method

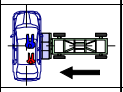
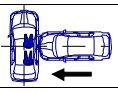
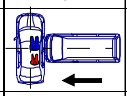
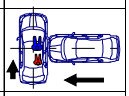
In order to understand the injury situation in side collision accidents and to investigate the occupant protection in side collisions, two series of crash tests were carried out using a car. In test series of Tests 1 to 4, Sedan 1 was used as a struck car. In the test series of Test 5 to 7, Sedan 2 was used. Table 3 presents the test car specifications, and Table 4 presents the test matrix. Tests were conducted based on the specifications of Regulation ECE/R95. An ES-2 dummy was seated in the stuck side of the front seat. Figure 9 shows the car test configurations and conditions. Figures 10 and 11 show the dummy postures before and after test, respectively. In Tests 1, 2, 3, and 4, the influence of car types on the occupant injury measures was examined. In Test 1 to 4, an ECE R95 moving deformable barrier (MDB), Sedan 1 (same car model as used for the struck car), and 1BOX vehicle were used as the striking cars. The impact velocity ranged from 48 to 50 km/h (Tests 1 to 6). A side impact test with two moving cars using the same car model (Sedan 1) for the striking and struck vehicles also was conducted to simulate a real car-to-car accident (Test 4). In Test 4, the velocities of the striking car and struck car were 48 and 24 km/h, respectively.

In Tests 5 and 6, the effectiveness of the CSAB was examined. The ECE R95 MDB impacted the Sedan 2 at 50 km/h. Considering the occupant posture survey that the head can contact with B-pillar, Tests 5 and 6 were prescribed to investigate the effect of the CSAB and SAB (torso side airbag) to when the occupant head would make contact with the B-pillar with and without these devices. Therefore, for Tests 5 and 6, the seat position was adjusted so that the dummy head overlapped the B-pillar. The CSAB was not equipped in the Sedan 2 in Test 5 and was equipped in the Sedan 2 in Test 6. Test 7 is the JNCAP test of Sedan 2, from which data was used for reference, though the impact velocity of the MDB was 55 km/h. In this paper, results of only the front seat dummy are discussed even though there were rear seat occupants in some tests.

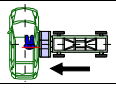
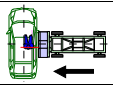
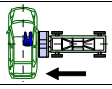
**Table 3 Specification of tested vehicles**

| Type | MDB (ECE/R95) | Sedan 1 | Sedan 2 | 1BOX |
|---|---|---|---|---|
| Kurb mass | 948 kg | 1100 kg | 1130 kg | 1370 kg |
| Engin displacement | - | 1498 cc | 1496 cc | 1789 cc |
| Dimension ( L x W x H) | 500 x 1500 x 500 ( Barrier Face ) | 4395 x 1695 x 1535 | 4410 x 1695 x 1460 | 4285 x 1635 x 1980 |

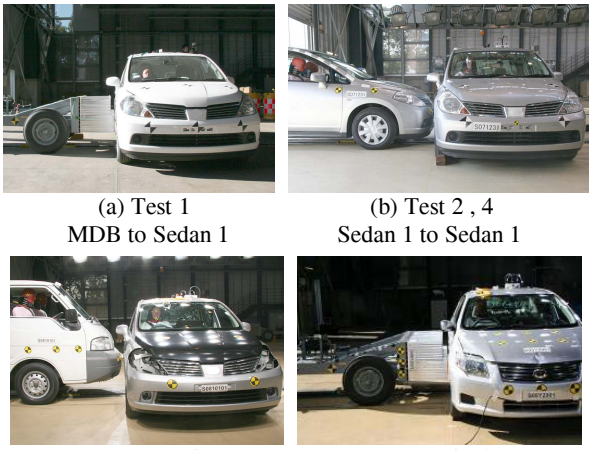
**Table 4 Test configurations**

| Test No. | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Test config. | |  |  |  |  |
| Impact velocity | | 50 km/h | 50 km/h | 50 km/h | 48 x 24 km/h |
| Impact Point | Striking vehicle | Vehicle C/L | Vehicle C/L | Vehicle C/L | Vehicle C/L |
| | Struck Car | SRP | SRP | SRP | SRP |
| Striking vehicle | Type | ECE/R95 MDB | Car (Sedan 1) | Vehicle (1BOX) | Car (Sedan 1) |
| | Mass | 948 kg | 1257 kg | 1553 kg | 1195 kg |
| Struck car | Type | Car (Sedan 1) | Car (Sedan 1) | Car (Sedan 1) | Car (Sedan 1) |
| | Curtain air bag | without | without | without | without |
| | Mass | 1194 kg | 1257 kg | 1240 kg | 1240 kg |
| | Front Dummy | ES-2 | ES-2 | ES-2 | ES-2 |
| | Rear Dummy | SID-IIs | ES-2 | SID-IIs | SID-IIs |

C/L: Center line
SRP: Seating reference point of driver in front seat

| Test No. | | 5 | 6 | 7 |
|---|---|---|---|---|
| Test config. | |  |  |  |
| Impact velocity | | 50 km/h | 50 km/h | 55 km/h |
| Impact Point | Striking car | Vehicle C/L | Vehicle C/L | Vehicle C/L |
| | Struck car | SRP | SRP | SRP |
| Striking vehicle | Type | ECE/R95 MDB | ECE/R95 MDB | ECE/R95 MDB |
| | Mass | 948 kg | 948 kg | 948 kg |
| Struck car | Type | Car (Sedan 2) | Car (Sedan 2) | Car (Sedan 2) |
| | Curtain air bag | without | with CSAB and SAB | without |
| | Mass | 1253 kg | 1279 kg | 1192 kg |
| | Front Dummy | ES-2 | ES-2 | ES-2 |

C/L: Center line
SRP: Seating reference point of driver in front seat



(a) Test 1
MDB to Sedan 1

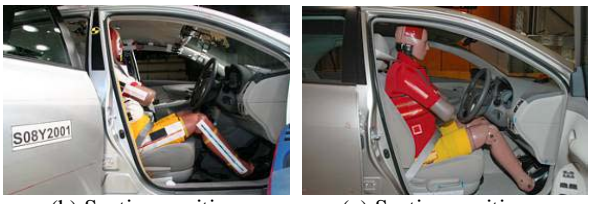
(b) Test 2 , 4
Sedan 1 to Sedan 1

(c) Test 3
1BOX to Sedan1

(d) Test 5 , 6 ,7
MDB to Sedan2

**Figure 9 Test vehicles before crash tests**

(a) Seating position (Sedan 2: Test 1,2,3,4 )




(b) Seating position
(Sedan 2: Test 5, 6)

(c) Seating position
(Sedan 2: Test 7)

**Figure 10 Photo of dummy seating position before tests. Parenthesis indicates the struck car**

(a) Seating Position (Sedan 1: Test 5)

(b) Seating position
(Sedan 2: Test 6)

(c) Seating position
(Sedan 2: Test 7)

**Figure 11 Photo of dummy seating position after tests. Parenthesis indicates the struck car**

## Test Results

### Comparison by striking cars (Test 1 to 4)

The struck car deformation and dummy injury measures were compared from Test 1 to 4. Figure 12 shows the car exterior deformation at the dummy thoracic level, H-point level, and side sill level. In the front seat location (2170 mm) at the thoracic level for the struck car, the deformation increased in the ascending order of the striking vehicle being the Sedan 1 (both cars moving, Test 4), MDB (Test 1), Sedan 1 (Test 2), and 1BOX (Test 3). At the hip point level, the deformation was smallest when the Sedan 1 (Test 4) was the striking vehicle, whereas the deformations were similar when impacted by 1BOX (Test 3), MDB (Test 1) and Sedan 1 (Test 2). At the side sill level, the deformation increased in the ascending order of the striking vehicle being the Sedan 1 (Test 4), Sedan 1 (Test 2), MDB (Test 1) and 1BOX (Test 3). Accordingly, overall the deformation of the struck car was largest when struck by the 1BOX. The flat shape and stiffness of the 1BOX probably affected the deformation of the struck car. The deformation of the struck car was comparable when struck by the MDB and Sedan. When the struck car was moving (Test 4), the deformation of the struck car was smallest among the test series.

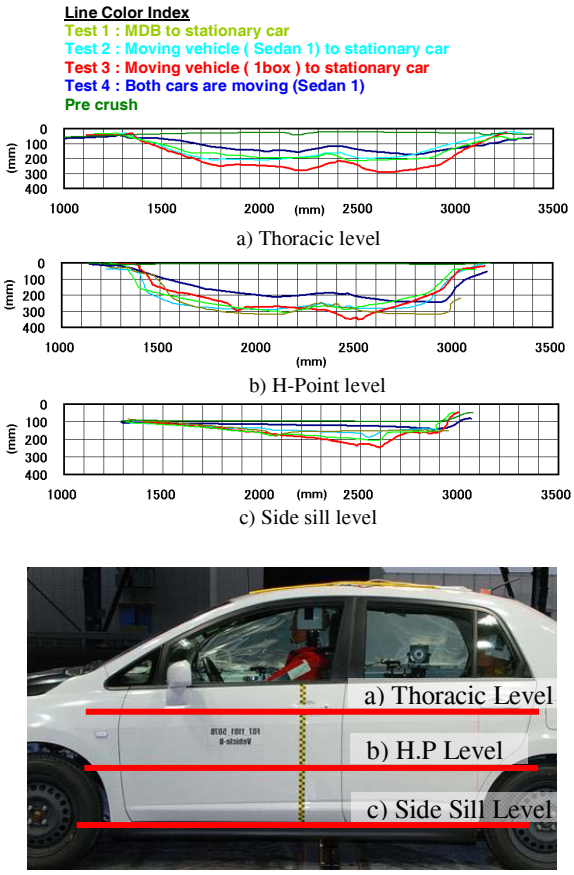
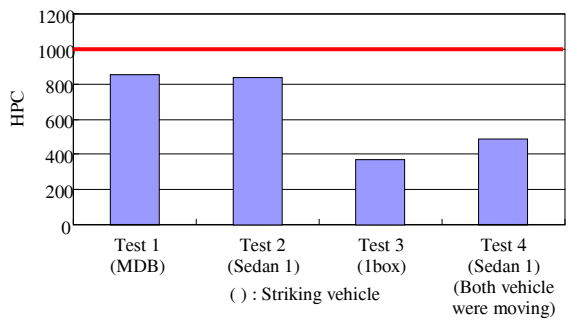


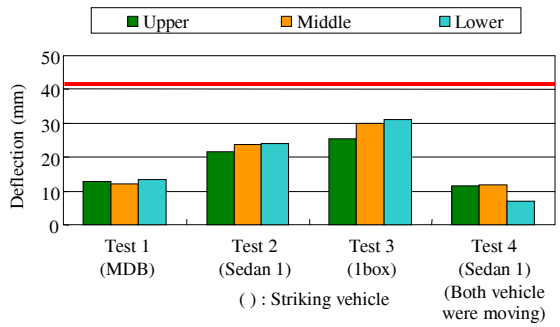

**Figure 12 Exterior panel deformation of Sedan 1**

Figure 13 shows the injury measures of the front seat ES-2 dummy in the Sedan 1 with the various striking vehicles. In Tests 1 and 4, all injury measures of the ES-2 were less than the acceptance levels of ECE R95. The HPC of the dummy in Sedan 1 struck by the 1BOX (Test 3) and Sedan 1 (both car moving, Test 4) were about 400, which were smaller than the values when stuck by the Sedan 1 (Test 2) and MDB (Test 1). The thoracic rib deflection was larger in the ascending order of the striking vehicle being the Sedan 1 (both car moving, Test 4), MDB, Sedan 1, and 1BOX. The lower rib deflection was larger than the upper and middle rib deflection except in Test 4 for the moving vehicle to moving vehicle test. The V*C exhibited a similar trend as the rib deflection. The abdominal force and pubic force of the ES-2 were comparable when struck by Sedan 1, irrespective of whether the struck car was moving (Test 2 and Test 4). The V*Cs were smaller than in these two tests then those measured when the striking vehicles were the 1BOX and MDB.

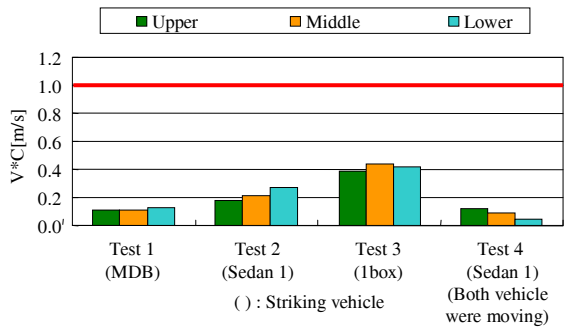
Figure 14 shows the ES-2 dummy kinematic behavior at the time the head resultant acceleration was maximal. When struck by the 1BOX (Test 3), the head of the ES-2 rotated around the x- (anterior-posterior) axis toward the striking vehicle, whereas the head orientation was close to a vertical position in the other tests. In the impact by the 1BOX, the door deformation of the struck car at the thoracic level was large, which led to a large displacement of the ES-2 torso. Then, the head moved toward the inboard side of the car, and it is likely that the head contact velocity with the roof side rail was small. As a result, the HPC was small while the rib deflection was large when struck by 1BOX.



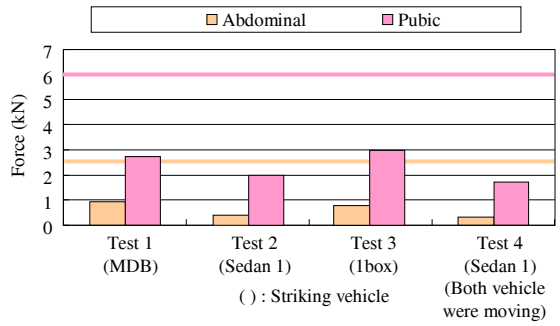

(a) HPC




(b) Thoracic rib deflection

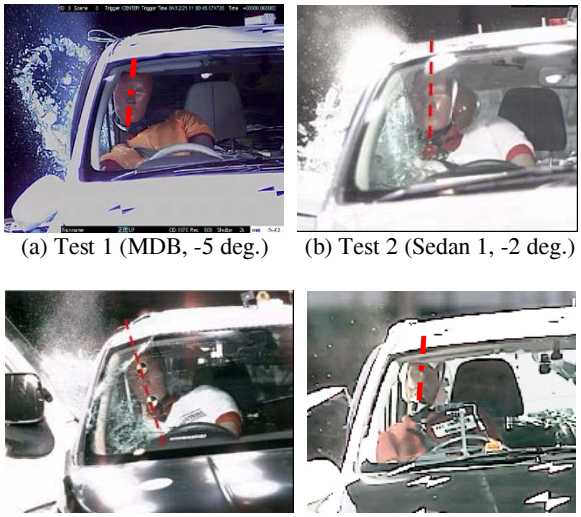



(c) Thoracic rib V*C




(d) Abdominal and public forces

**Figure 13. Injury measures of ES-2 in front driver seat in struck car (Sedan 1).**



(a) Test 1 (MDB, -5 deg.) (b) Test 2 (Sedan 1, -2 deg.)

(c) Test 3 (1BOX, 19 deg.) (d) Test 4 (Sedan 1, -3 deg.) Both cars were moving

**Figure 14 Dummy behavior at the time of maximum resultant head acceleration; parenthesis indicates striking vehicle and inclination angle of dummy head**

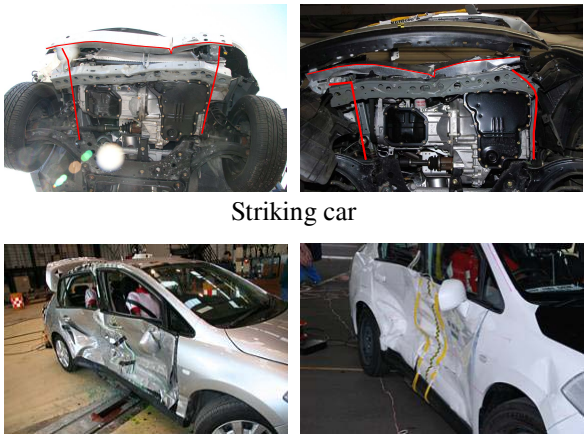
## Comparison by moving and stationary struck cars (Test 2 and 4)

In Tests 2 and 4, the car-to-car tests were conducted using the same models (i.e., both the striking and the struck vehicles were a Sedan 1). In Test 2, the struck car was stationary, and in Test 4 the struck car was traveling at 24 km/h. The influence of a moving struck car was examined based on the results of these two tests. Figure 15 shows the head contact locations in the struck cars for Test 2 and Test 4. The head contact locations in the struck car were similar in both tests, which demonstrate that the head contact velocity in the A-P direction was relatively small even though the struck car was moving in Test 4. The HPC and rib deflection was large when the struck car was stationary (see Figure 13).

Figure 16 shows the struck car deformations in Tests 2 and 4. The deformation of the striking car was larger when the struck car was moving. On the other hand, the deformation of the struck car was larger when the struck car was stationary. In Test 4, the longitudinal member bent laterally in the direction that the struck car was moving. Accordingly, it is likely that the effective stiffness of the striking car was smaller when the struck car was moving than when the struck car was stationary. In Test 4, where both cars were moving, the deformation of the struck car was relatively small but was distributed more widely in the struck car's longitudinal direction (Figure 12 and 16).

Test 2 Test 4

**Figure 15 Head contact location in the struck car when struck car was stationary (Test 2) and moving (Test 4)**



Striking car

Struck car

Test 2 Test 4

**Figure 16 Car deformation when struck car was stationary (Test 2) and moving (Test 4)**

## Comparison between a curtain side air bag equipping car and a non-equipping car

Based on Tests 5, 6, and 7, the effect of a CSAB was examined. In Tests 5 and 6, the dummy's head was aligned to overlap the B-pillar, and the CSAB and SAB were installed in Test 6. In Test 7 (i.e., the JNCAP test), the impact velocity of the MDB was 55 km/h and the dummy torso made contact with the door.

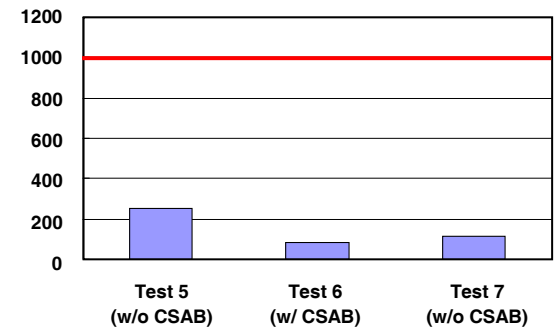
Figures 17 and 18 show the dummy injury measures and the time histories of the dummy readings. The HPC in Test 6 where the CSAB deployed and made contact with the head was 86, which was less than those for Test 5 (255) and Test 7 (113), which were conducted without a CSAB installed. As shown in the head resultant acceleration-time histories [see Figure 18(a)], in the case with a CSAB installed (Test 6), the CSAB deployed between the head and the B-pillar within 20 ms after the collision, the head was accelerated earlier in the crash event, and the peak acceleration was small. In contrast, in the case of the

struck car not having a CSAB installed (Test 5), the head made contact with the B-pillar at the velocity of the B-pillar intrusion, the head acceleration increased suddenly, and the peak was relatively high.

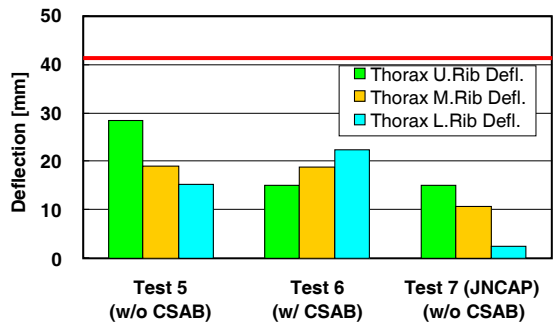
The rib deflection was smaller in the test with the CSAB installed than that without the CSAB. The rib deflection was smallest in JNCAP test where the chest made contact the door (Test 7). Accordingly, it is likely that the B-pillar has a higher potential of causing thoracic injuries than the door with respect to the rib deflection. The lower rib deflection was larger than the upper rib deflection in Test 6 probably because the SAB deployed. As shown in the time history of rib deflections [see Figure 18(b)], the lower deflection increased earlier during the crash event as compared to the upper rib. The rib deflection could be smaller with an optimization of the SAB design.

The V*C of thoracic upper rib, middle rib, and lower rib was compared in Figure 17(c). The trend of the V*C responses in these tests were comparable to those of the rib deflections.

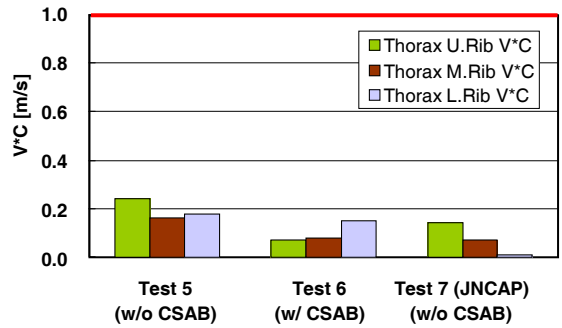
Figure 17(d) shows the abdominal and pubic forces. The abdominal force and pubic force do not change appreciable, irrespective of the CSAB equipment. In Test 7 (i.e., the JNCAP test), the abdominal force was larger and the pubic force was smaller as compared to Tests 5 and 6. Therefore, it is likely that the B-pillar has more of an injury potential to the upper torso as compared to the lower torso. Figures 18(c) and 18(d) show the time histories of abdominal force and pubic forces. Although there were differences in the abdominal force in Tests 5, 6, and 7, the pubic forces in these tests were comparable. Since the pelvis was not covered with the SAB, and the gap between the pelvis and B-pillar (Tests 5 and 6) and that between the pelvis and door (Test 7) would be comparable.



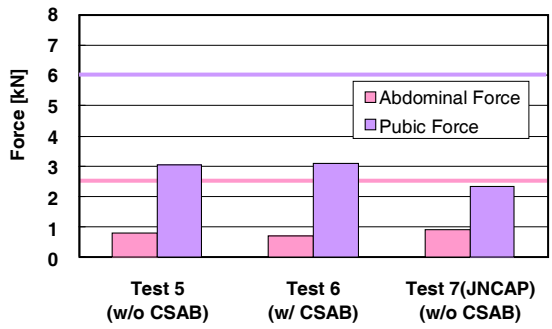

(a) HPC




(b) Thoracic rib deflection

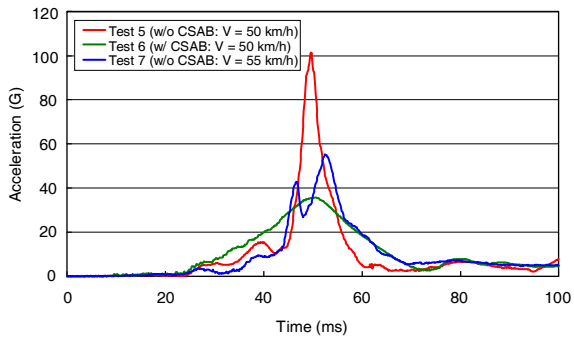



(c) Thoracic rib V*C

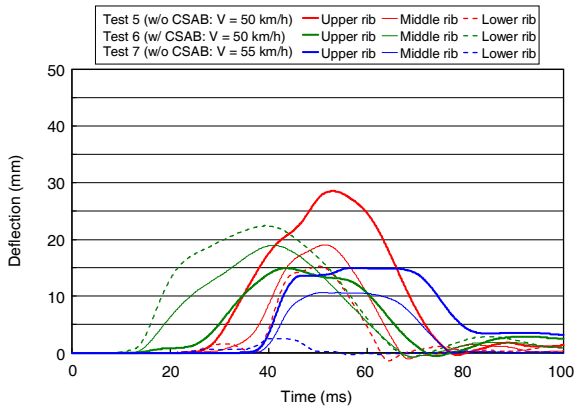



(d) Abdominal and pubic force

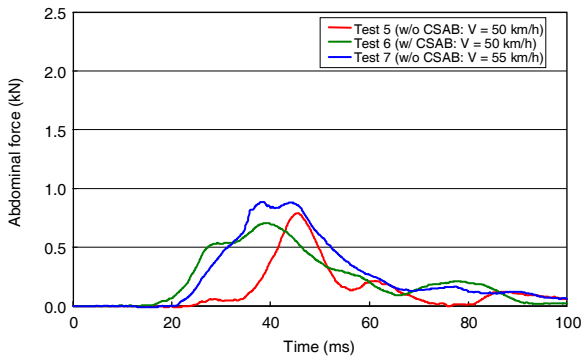
**Figure 17 Injury criteria of ES-2 seated in front seat (Test 5, 6 and 7).**



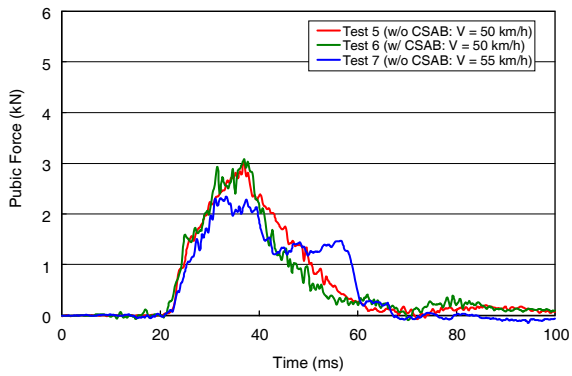

(a) Head resultant acceleration




(b) Thoracic rib deflection




(c) Abdominal force




(d) Pubic force

**Figure 18 Injury parameter time histories of ES-2 in Test 5, 6, and 7.**

## DISCUSSION

Accident analyses were conducted using police data. Sixty percent of the fatal and serious injuries to front seat occupants in side collisions were to those seated on the struck side, and 40% were to those seated on the non-struck side. The percentage of thoracic injuries was large, whereas that of the neck injuries was small when the striking vehicle was an 1BOX, SUV, or truck. The percentage of pillars being among the injury causes for head injuries was only 5.4%. A field survey of the occupant posture was conducted, and it was shown that 50% of the driver head locations overlapped the B-pillar. In order to understand this difference in the percentage of B-pillar as injury causes of the head, it is necessary to conduct further in-depth accident analyses.

The deformation and injury risk of the occupants in the struck cars are affected by the striking vehicles. Based on the accident analysis, the percentage of chest injuries was large when the struck vehicle was impacted by an 1BOX. In Test 3, the 1BOX impacted the Sedan 1. Since the 1BOX has a high leading edge, the loading and the deformation of the struck car at the thoracic level was large. This deformation mode of the struck car led to large thoracic deflection of the dummy.

The effect of struck car movement was examined by conducting car-to-car tests (Tests 2 and 4). In Test 2, the struck car was stationary, and in Test 4 struck car was traveling at 24 km/h. The injury measures of the ES-2 seated in the struck car were smaller when the struck car was traveling compared to those when the struck car was stationary. In the car-to-car crash, when the struck car was traveling, the longitudinal members of the striking car bent laterally. As a result, the stiffness of the front structure of the striking car possibly may be less stiff than that for the striking car in Test 2. (In Test 2, the struck car was stationary and the longitudinal members of the striking car collapsed in an axial mode.) In Test 4, where both cars were moving, the deformation of the struck car was distributed widely in the struck car's longitudinal direction. The delta-V in the lateral (i.e., L-R) direction of the struck car was lower when the struck car was moving than when the struck car was stationary. The less stiff deformation mode of the striking car and the wide distribution of the struck car deformation led to a lower intrusion velocity and smaller intrusion of the struck car. As a result, the injury measures of the dummy in the struck car were smaller. In Test 4, because the impact force applied by the striking car to the struck car was small, the acceleration in the longitudinal direction of the struck car was small. Accordingly, the dummy movement in the A-P direction in the struck car was small in Test 4, and the dummy behavior was comparable between Tests 2 and 4.

Based on the field survey of occupant posture, it is probable that the occupant head makes contact with the B-pillar in side impact accidents. To understand the head injury risk in contact with B-pillar and its protection by the CSAB, Tests 5 and 6 were carried out with a dummy posture that the head overlapped the B-pillar. In Test 5, the head was impacted by the B-pillar at the intrusion velocity of the B-pillar, and the peak of the head acceleration was high. The HPC in the Test 5 was less than the injury assessment reference value possibly because of the energy absorbing structure in the B-pillar. In Test 6, the struck vehicle was equipped with a CSAB and SAB. The CSAB deployed and decelerated the head at an early stage of the impact, and thereby effectively reduced the head acceleration. It is likely that the CSAB is effective for reducing head injury risk in the case where the head would make contact with B-pillar.

## CONCLUSIONS

In order to discuss potential side impact test procedures for the future and to identify the issues in side collisions, accident analyses, a field survey of occupant posture, and crash tests were carried out. The results are summarized as follows:

1. From accident analyses using police data, 60% of the fatal and serious injuries to front seat occupants in side collisions were to the struck side occupants, and 40% were to the non-struck side occupants. The percentage of thoracic injuries was larger as the striking vehicle was the 1BOX, SUV, or truck.

2. Based on the field survey on the road, it was shown that 50% of driver heads overlapped the B-pillar. Accordingly, it is predicted that the head will make contact with the B-pillar which can lead to head injuries.

3. The deformation and injury measures of the dummy of the struck car were affected by the properties of the striking car. When the 1BOX vehicle, which has a flat front shape and a stiff front structure, impacted the side of the car, the thorax was impacted because of the large deformation of the belt-line of the struck car. As a result, the HPC of the dummy in the struck car was small and the chest deflection was large.

4. The effect of struck car movement was examined from the car-to-car tests. When the struck car was moving, the loading and the deformation of the struck car was small, and the injury measures of the dummy in the struck car were smaller than those for when the test was conducted with the struck car being stationary.

5. The effect of CSAB was examined in the case where the dummy placement resulted in the dummy head being overlapped with the B-pillar. The CSAB decelerated the head at the early stage of the impact, and thereby effectively reduced the head acceleration. It is likely that the CSAB is effective for reducing head injury risk as compared to the case where the head otherwise would make contact with the B-pillar.

## ACKNOWLEDGEMENT

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