## RECONSTRUCTIONS OF REAL-LIFE SIDE IMPACT COLLISIONS

F. BRUN-CASSAN, Y. PINCEMAILLE, C. TARRIERE
Laboratory of Physiology and Biomechanics
Associated with Peugeot SA/Renault
132 Rue des Suisses
92000 NANTERRE - FRANCE*

### ABSTRACT

Within the frame of the Joint Biomechanical Research Project, five actual lateral car to car collisions were reconstructed by means of 18 dummy tests and 14 cadaver tests. A first synthesis of the results obtained was presented in the summer of 1981. Additional research efforts were thought desirable ; corresponding results, based on the available data material, are the subject of this communication.

### INTRODUCTION

Five actual lateral car to car collisions were reconstructed several times with dummies and cadavers in the frame of the "Joint Biomechanical Research Project KOB". These accidents were selected because, as regards their violence, they are representative of those actual accidents for which the safety problems are being studied and improvements are likely to be efficient.
Accelerometric measurements were performed on the different body segments of dummies and cadavers ; post-mortem examinations were made systematically for each cadaver, allowing comparison of injuries with those of the actual victims.
As regards vehicle deformations, all the reconstructions were estimated satisfactory concerning the deformations of the side-wall of the struck car, at the level of the occupant seated on the side of impact.
Great differences were found between the PART 572 dummy and cadavers for all body segments, except for the pelvis, confirming that this dummy is unsuitable for use in side collisions.
The differences observed in injury levels between the different cadavers were accurately explained by differences in their bone conditions. Taking it into account, the lesional levels sustained by the real victims and the cadavers were very coherent at thorax and pelvis levels.
The analysis confirms that deflection of the thorax, taking into account the bone condition of the subjects, is the parameter the more related to the injury severity level of the thorax.

---

* The synthesis of this work was performed by the Laboratory of Physiology and Biomechanics.
The research was supported in part by CCMC, BAST and FAT contracts.

As regards pelvis, only few lesions were found and the high values recorded for the pelvis accelerations would seem to indicate that the tolerance of living persons in side collisions might be higher than 100 g/3 ms. Accidentological analysis and reconstructions with cadavers point out the necessity of using a specific abdominal criterion for protecting abdominal area. The comparison of results obtained in the frame of this program with those of FAT/HEIDELBERG study for instance, shows globally a good agreement ; the kinematics and loadings of dummies and cadavers are different in most of the body regions investigated. That is the reason why specific dummies have to be used as test devices for side impact simulations.

## I. THE SELECTED CASES AND THEIR COMPARISON WITH ACTUAL ACCIDENTS

### 1. Description of selected cases

Five actual lateral car to car collisions were reconstructed in the following way :

- PEUGEOT 304/RENAULT 15 : 12 reconstructions (6 with PART 572 dummy, 3 with APROD dummy and 3 with cadavers) ;
- PEUGEOT 504/CITROEN LN : 7 reconstructions (4 with PART 572 dummy and 3 with cadavers) ;
- PEUGEOT 504/PEUGEOT 504 : 8 reconstructions (5 with PART 572 dummy and 3 with cadavers) ;
- LEYLAND MINI/FORD CAPRI : 8 reconstructions (5 with PART 572 dummy and 3 with cadavers) ;
- FORD TAUNUS/VOLKSWAGEN PASSAT : 7 reconstructions (5 with PART 572 dummy and 2 with cadavers).

The main characteristics of these collisions are summarized in table 1. These cases belong to a particular sub-sample of the car occupants involved in side collisions ; they are always nearside impact occupants, with intrusion of the passenger compartment concerning them.

### 2. Comparison with actual accidents

The figure 1 shows the cumulative frequencies of the variation in velocity for the struck car ($\Delta V$) for lateral collisions involving nearside occupants with intrusion. For instance, with a $\Delta V$ of 25 km/h, the following population will be concerned :

- 55 % of the occupants involved,
- 35 % of the seriously injured, APR data (1)
- 10 % of the fatally injured.

One may see that the selected cases are not extreme as regards their $\Delta V$ ; for instance, $\Delta V$ for 304/R15 collision is such that 65 % of $\Delta V$ for all collisions involving nearside occupants are lower, but 45 % if we consider only accidents with seriously injured people and 15 % for killed people. So, from this APR distribution (Figure 1) and from Hannover data (2), these accidents appeared to be interesting for reconstructions, as they correspond to a violence for which safety improvements are likely to be efficient.

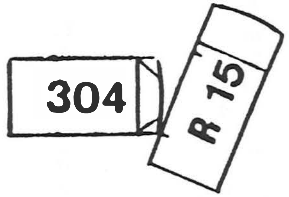
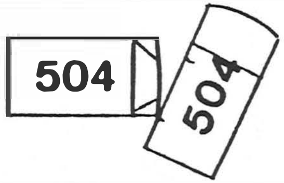
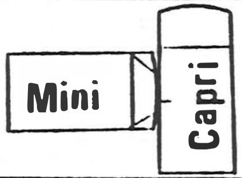
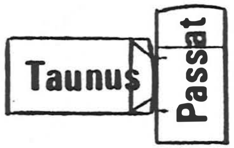
| Case Nb | Type of vehicle and year of manuf. | Sketchplan | Angle ° | Speed Kph | Mass ratio | Vehicle occupation | Restraint systems |
|---|---|---|---|---|---|---|---|
| 1 | 304 Peugeot (1974)<br>R15 Renault (1973) |  | 70 | 55 | 1.07 | Driver<br>Driver | 3 pts energy absorber<br>Unbelted |
| 2 | 504 Peugeot<br>LN Citröen |  | 100 | 45 | 0.61 | Driver<br>Driver | Unbelted<br>Retractable belt |
| 3 | 504 Peugeot<br>504 Peugeot |  | 75 | 65 | 1. | Driver<br>Front pass.<br>Driver | Belted<br>Belted<br>Unbelted |
| 4 | B.L. mini 1000<br>Ford Capri 1300 |  | 90 | 80 | 1.61 | Driver<br>Passenger<br>Driver | Static belt<br>Unbelted<br>Static belt |
| 5 | Ford Taunus<br>V.W. Passat |  | 90 | 72 | 0.78 | Driver<br>Driver<br>Front pass. | Belted<br>Belted<br>Unbelted |

Table 1. Characteristics of the reconstructed accidents

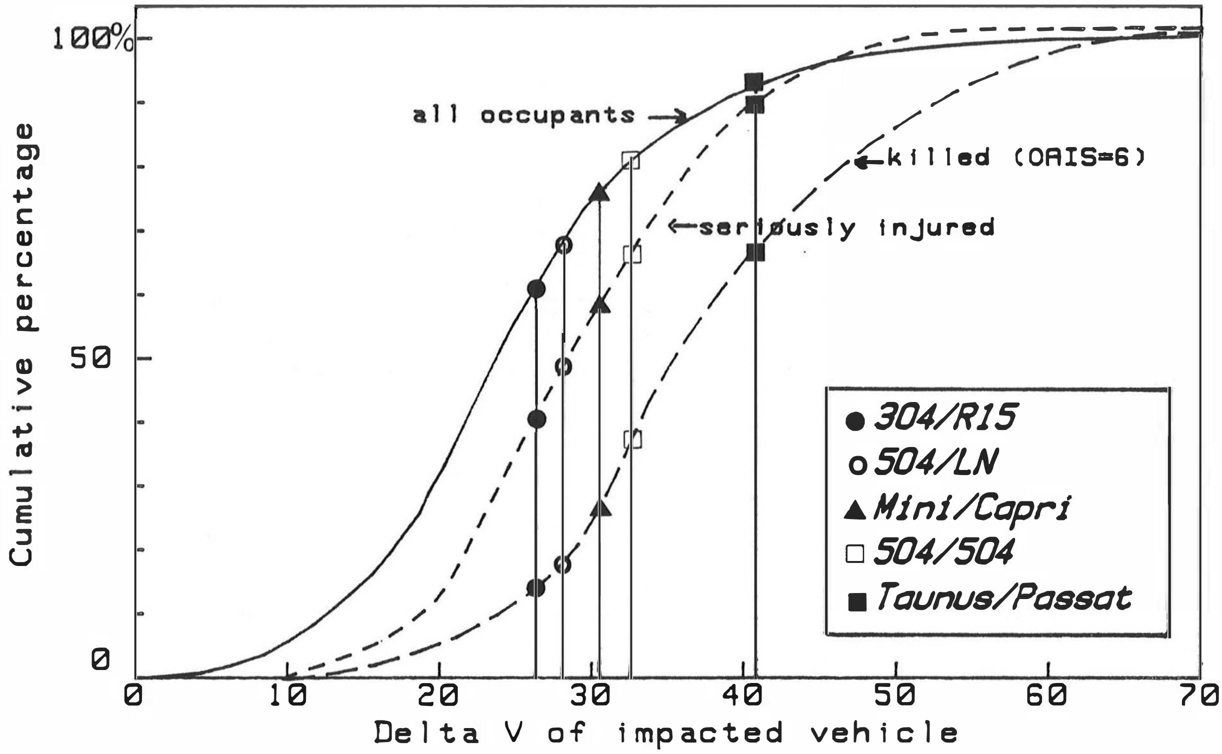



Figure 1. Cumulative percentage for nearside occupants with intrusion versus $\Delta V$ of impacted vehicle

## II. PARAMETERS MEASURED AND METHODOLOGY

In the actual accidents :
For most of the cases, the following data were collected in actual accidents :

- The type of vehicles and year of manufacturing,
- An estimation of the collision speed and angle between the directions of the two cars,
- A sketchplan of the accident,
- The localizations of contact points on the cars, as well as the external and internal deformations of the two cars,
- The areas of contact in the passenger compartment,
- The number of occupants, their anthropometrical characteristics and a detailed description of the injuries sustained by them,
- Utilization (or not) of restraint systems.

In the reconstructions :

- For the cars

Accelerometers were fixed on the structures of the cars at specified localizations :

- B-pillar : accelerometers on the left and right B-pillars for both cars (striking and struck),
- A-pillar : one accelerometer for the struck car,
- Rear-cross member : a triaxial accelerometer on the floor along the longitudinal axis of the struck car,
- Doors : four uniaxial accelerometers on the door of the struck car (impacted side).

- For the occupants

The parameters recorded on the human surrogates were the following :

- For the dummies (Hybrid II and APROD)
    - one triaxial accelerometer at the center of gravity of the head,
    - one triaxial accelerometer in the thorax,
    - one triaxial accelerometer in the pelvis,
    - a force transducer in each femur.

For the APROD dummy, supplementary measurements were made : accelerations were recorded at the levels of third and sixth ribs, on the impacted side, and the deflection of the thorax was measured by means of an optoelectronic system.

- For the human subjects

The measurements are more numerous ; they are of three types :

- anthropometrical measurements before the tests (3),
- accelerometric and kinematics measurements during occurence of impact, by means of :
    . for the head : nine linear accelerations with three triaxial accelerometers screwed on the skull,
    . for the thorax : eighteen accelerations in different localizations : four triaxial on the spine (T1, T4, T7 and T12), two uniaxial on the sternum (upper and lower parts) and one uniaxial on the external parts of the right and left 4th and 8th ribs, measurements of deflection of the thorax,
    . for the pelvis : one triaxial acceleration at the level of the sacrum,
- X-rays and post-mortem examinations after the tests, including biological analysis with the aim of characterizing the bone condition of the subjects (4).

## III. MAIN RESULTS FROM THIS PROJECT

As regards vehicle deformations, all the reconstructions were estimated satisfactory concerning the deformations of the side-wall of the struck car, at the level of the occupant seated on the side of impact.
This allows a comparison of the loads supported by the surrogates with those of the real victims.
The injuries suffered by the victims in real accidents and those of the cadavers are reported in table 2.

| CASE | | HEAD | THORAX | ABDOMEN | PELVIS |
|---|---|---|---|---|---|
| 304/RI5 | Real victim | Left parietal wound AIS 1 | 13 rib fractures with flail chest AIS 3 | — | — |
| | Cadaver 1 | — | 20 rib fractures with flail chest AIS 4 | — | — |
| | Cadaver 2 | — | 10 rib fractures AIS 3 | — | — |
| | Cadaver 3 | Haemorrhagic suffusions AIS 1 | 5 rib fractures + clavicle AIS 3 | — | — |
| 504/LN | Real victim | — | — | — | Fracture of left iliopubic ramus AIS 2 |
| | Cadaver 1 | Fracture of mandibule AIS 2 | 5 rib fractures AIS 3 | — | — |
| | Cadaver 2 | — | — | — | Right hip dislocation AIS 3 |
| | Cadaver 3 | Peripheral hemorrhages-small injury in cerebral trunk AIS 4 | 1 rib fracture AIS 1 | — | — |
| 504/504 | Real victim | Cranial traumatism AIS 2 | 6 rib fractures AIS 3 | Grazing of the liver bruizing of the left kidney AIS 4 | Fracture of the left cotyla and the left ischiopubic ramus AIS 3 |
| | Cadaver 1 | Haemorrhagic suffusions AIS 2 | — | — | — |
| | Cadaver 2 | — | 2 rib fractures + clavicle AIS 2 | — | — |
| | Cadaver 3 | Vascular lesions AIS 2 | 16 rib fractures + clavicle AIS 4 | — | — |
| MINI/CAPRI | Real victim | Head trauma AIS 1 | — | — | Pains of the hip AIS 1 |
| | Cadaver 1 | — | — | — | — |
| | Cadaver 2 | — | Fracture of 2 ribs + clavicle AIS 2 | — | — |
| | Cadaver 3 | — | — | — | — |
| TAUNUS/ PASSAI | Real victim | Short inconsciousness AIS 2 | — | — | Left itio and ischio pubic rami fractures AIS 3 |
| | Cadaver 1 | — | 3 rib fractures AIS 2 | — | — |
| | Cadaver 2 | — | Bilateral flail chest AIS 4 | Parenchyma tears AIS 3 | — |

Table 2. Injuries to the real victim and the cadavers in the reconstructions

FOR THE HEAD

Analysis of the kinematics of the head/neck/thorax body segments revealed in almost all cases an absence of cranial and/or cerebral injury, despite head impacts in all these cases ; the sideways displacement and bending of the head were limited by this impact.
There was only one case of severe brain stem injury in cadaver tests (AIS $\geq$ 4), without significant head impact (HIC = 100), but associated with a very particular kinematics ; it can be explained by a very extensive side bending of the head (head/thorax angle greater than 75°) which is no doubt responsible for the peripheric haemorrhaging that occured, as well as of the injuries to the brain stem.
For two other cases (Leyland mini/Ford Capri and Taunus/Passat), there was no cranial fracture in any case, explaining the head AIS equal to 0, but as there was no brain injection, no conclusion could be drawn as regards occurrence of cerebral injuries.
Figure 2 indicates head AIS for the cadaver reconstructions with corresponding calculated HIC values. In five cases AIS 0 or 1 were associated with HIC values no higher than 1000. In one case, a HIC value of 1980 was obtained, without any injury (AIS = 0). The head impact occured against the B-pillar. The calculated value of resultant acceleration is rather high (205 g) but it corresponds to an impact of short duration. If we take into account the bone caracteristics of the skull of this subject, two remarks can be made : the thickness of his skull was higher than the average thickness of other cadaver skulls and its SBCF classified him among subjects of better than average skull resistance. It was shown in a previous publication (5) that in impacts on parieto-temporal area, with subjects having the same SBCF as this cadaver, a level of 300 g's for head acceleration could be supported without occurrence of fracture in padded impacts. In this reconstruction, the head impact occured against the B-pillar, which resulted in a deformation of it ; so, this head impact can be compared to those referenced and it is not surprising that it could be associated with an AIS 0 for the head.

FOR THE THORAX

A detailed description of the injuries observed for the cadavers is given in table 2. For the three first cases, no internal injury was found, despite a flail chest in one case (with 20 rib fractures). For one reconstruction of Mini Capri, they were tears in the diaphragm, simultaneously with eight rib fractures (AIS = 3). In another case of Taunus Passat reconstruction, a cadaver sustained parenchyma tears, simultaneously with a bilateral flail chest (AIS = 4).
So, out of 14 reconstructions with cadavers, there were only two cases of internal thoracic injuries simultaneously with rib fractures.
In the actual accidents, none internal lesion was observed, though there were rib fractures in several cases, with a flail chest in one case.
Taking into account of these results, it can be stated that the number of rib fractures proves to be a suitable indicator of thorax injuries.

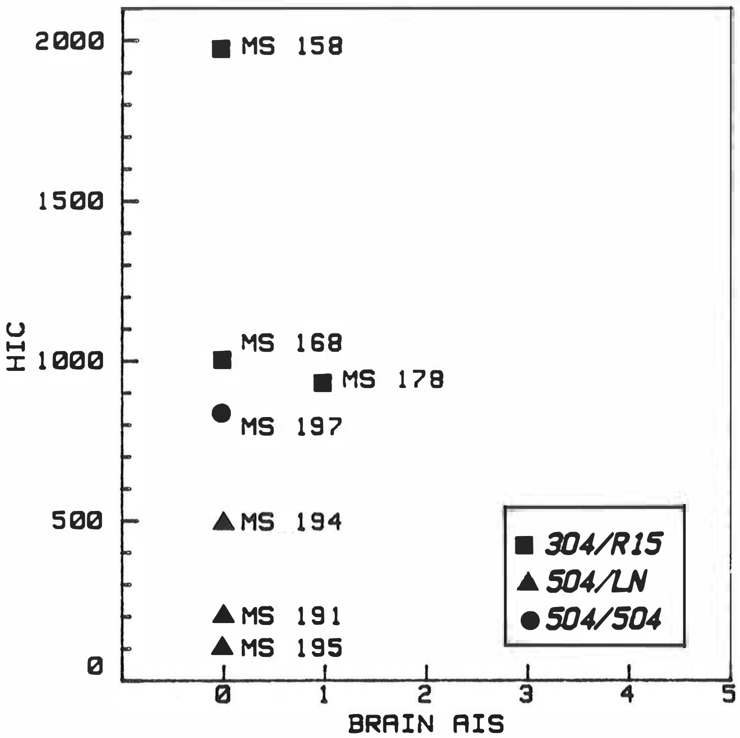



Figure 2. HIC versus AIS in the cadaver reconstructions

Accelerations of the thorax were measured according to the 12γ method for two of the five reconstructed accidents (504/LN and 504/504). The different values obtained are plotted versus the numbers of rib fractures on figures 3 to 5 and compared to other available data (6).

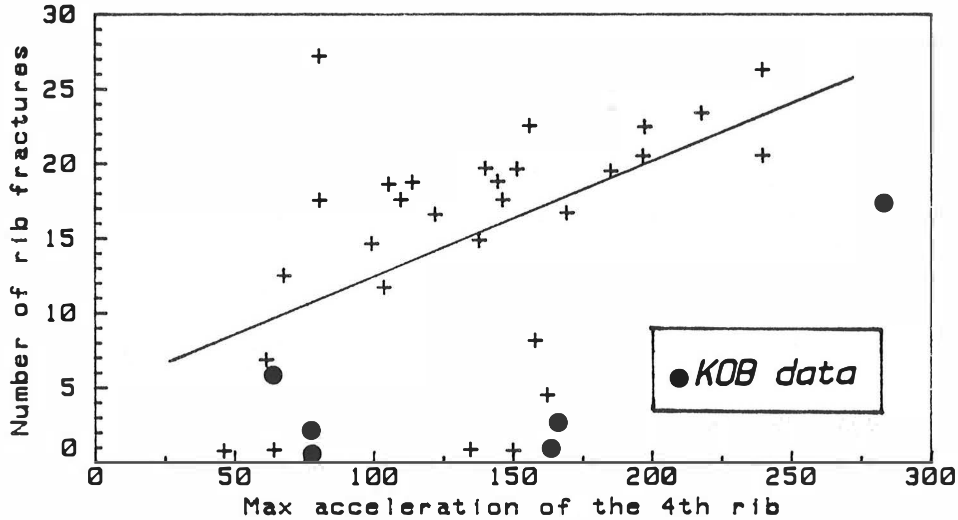



Figure 3. Lateral acceleration of the 4th rib and number of rib fractures

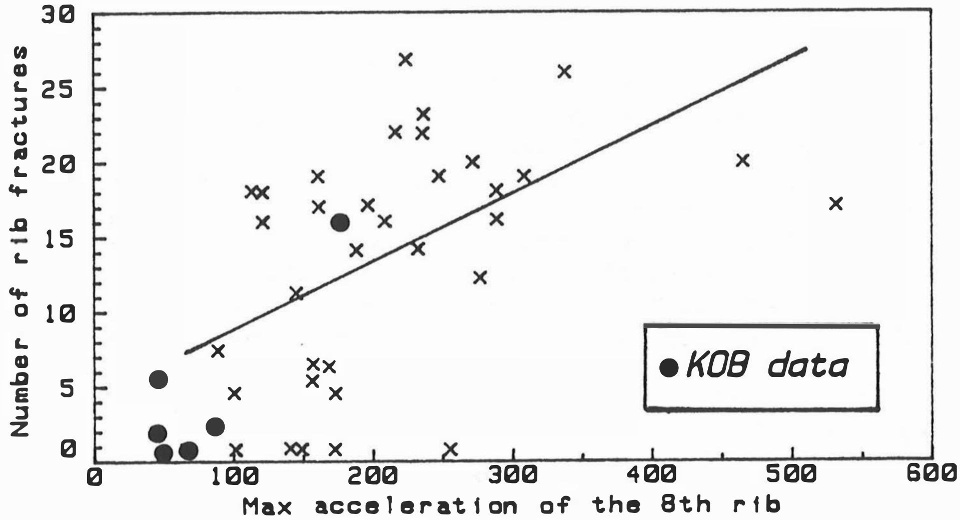



Figure 4. Lateral acceleration of the 8th rib and number of rib fractures

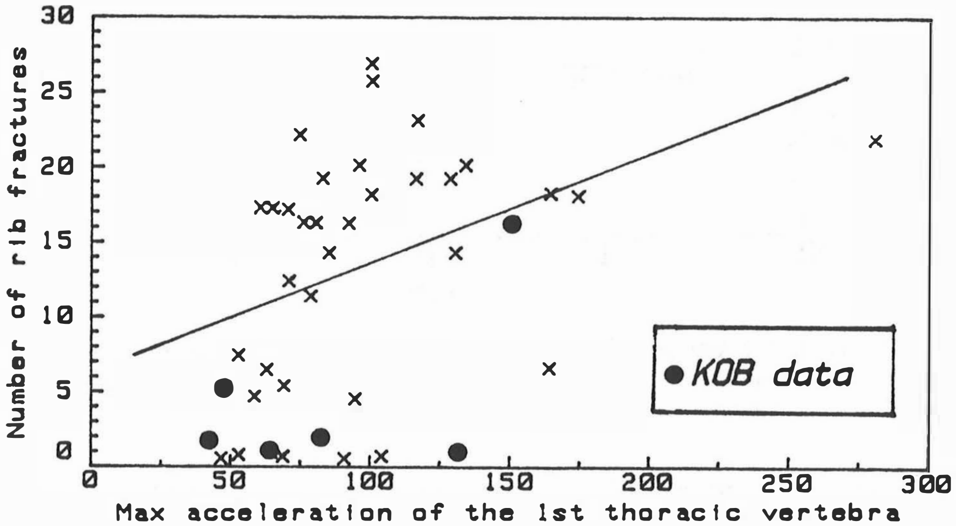



Figure 5. Lateral acceleration of the 1st thoracic vertebra and number of rib fractures

It can be seen that the KOB data differ much from the FAT/HEIDELBERG data. The number of rib fractures and the acceleration of the fourth rib appear not to be correlated when KOB data are added to the other (Figure 3). The same is less true as regards number of rib fractures versus acceleration of the 8th rib (Figure 4), which seems logical, given the localization of the impacts on the thorax.

By the way, the number of rib fractures versus lateral acceleration of the first thoracic vertebra yields a poor correlation (figure 5).
Possible relationships were also investigated between number of rib fractures and BLUR (7) but because of the restricted amount of data, it was difficult to pinpoint any relation. It turned out that it was necessary to take into account the subject's skeleton quality and to investigate possible relationship between BLUR and BCF. Figure 6 represents these two parameters, with the numbers of rib fractures indicated beside each point ; the lines connect points corresponding to subjects impacted under identical conditions (same reconstruction). The BLUR variations are extremely slight within a test series and BCF provides here a much better explanation of the differences in injury levels than does BLUR. BLUR emerges here only as an indicator of violence and is by itself insufficient to account for differences in injury levels under identical impact conditions. The same is true for average Power (8).

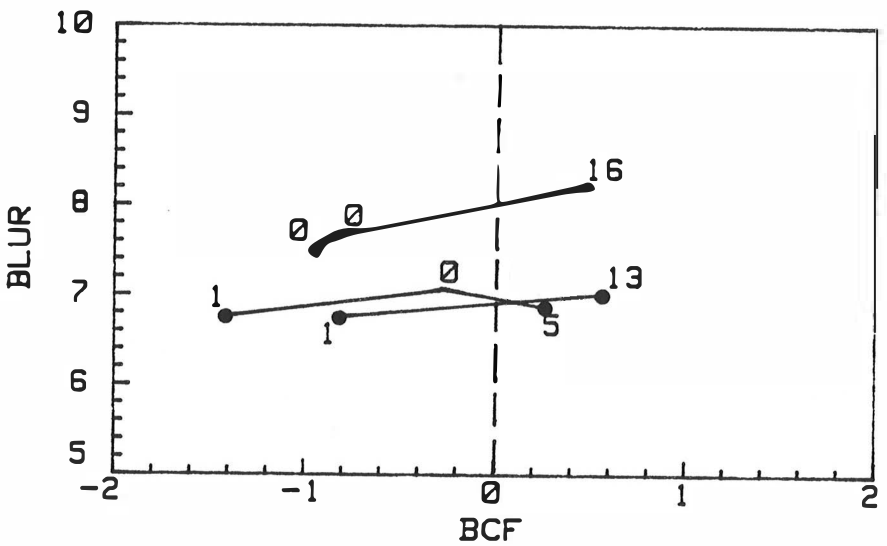



Figure 6. BLUR versus BCF for three of the KOB reconstructions
Points corresponding to a same reconstruction are linked together

Figure 7 shows the numbers of rib fractures versus the relative deflection of the whole thorax of the subject, when available.
With this reduced number of data, we can find a fairly good correlation between these two parameters, except for one subject who sustained only one rib fracture, associated with a relative thoracic deflection of 31 % ; such a case can be explained by the fact that this subject had a very good bone condition (BCF = - 1.4).*

---

* Such a case is not surprising ; it has been established that (12) if the number of 4 to 5 fractures is considered to be the reference limit, the thoracic tolerance of living persons (average BCF value = - 1.4) corresponds to a maximum relative deflection of the half thorax which is 38 %.

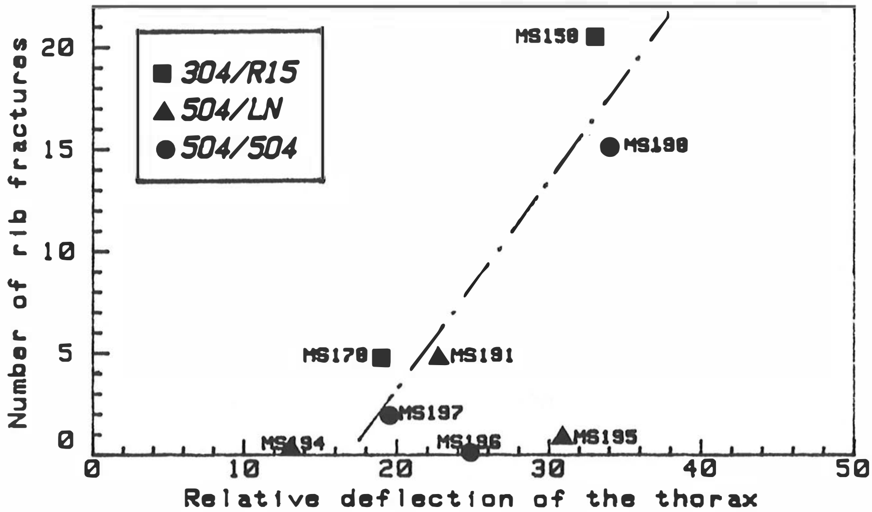



Figure 7. Number of rib fractures versus relative deflection of the whole thorax

Figure 8 shows the number of rib fractures versus BCF of the subjects ; the more the BCF is negative (good bone condition), the lesser is the number of rib fractures for subjects impacted under identical conditions.

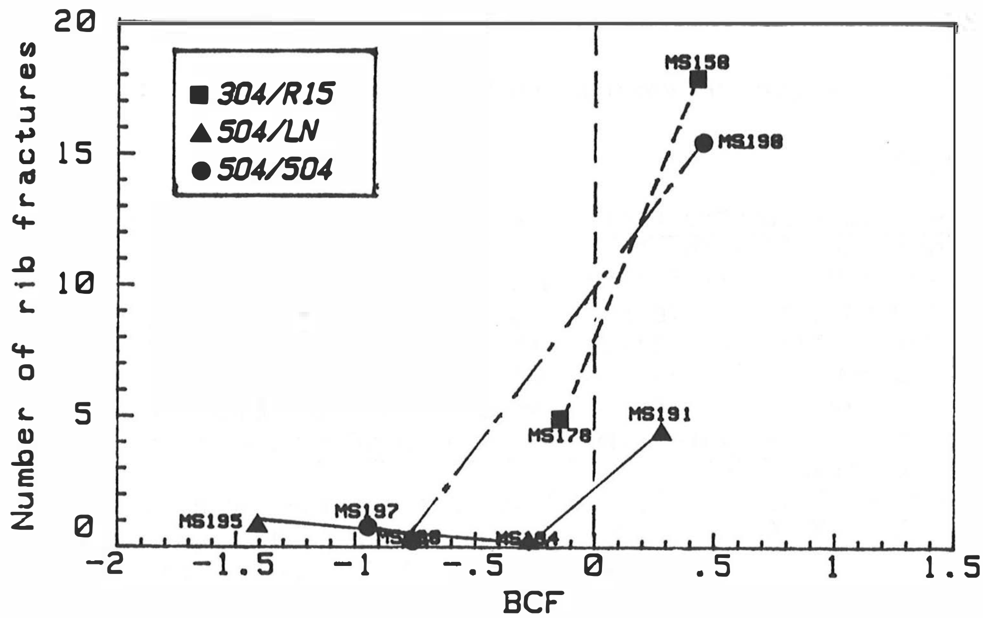



Figure 8. Number of rib fractures in terms of Bone Condition Factor (BCF) for the KOB reconstructions.Points corresponding to a same reconstruction are linked together (7).

We also tried to investigate relationships between severity of injuries and TTI (9). We reported on figure 9 the AIS values for hard thorax versus TTI ; KOB data are in the scatter of Eppinger data but they emphasize the fact that for a given TTI value, several AIS values may occur.
On the basis of these results, one concludes that deflection of the thorax, taking into account bone condition of the subjects, is the parameter the more related to the injury severity level of the thorax.

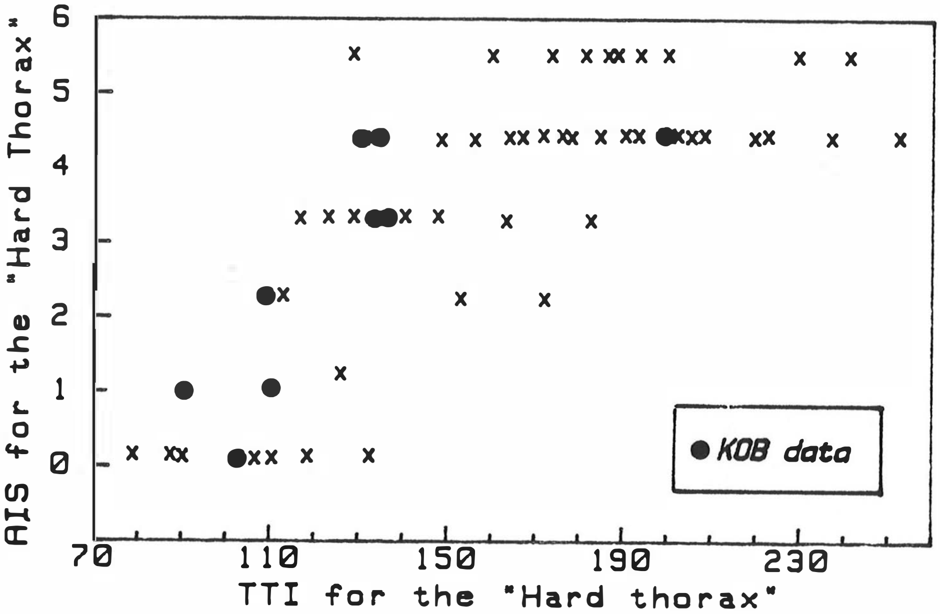



Figure 9. Maximum hard thorax AIS versus TTI

FOR THE PELVIS

In the 304/R 15 reconstructions, the 3 ms pelvis accelerations measured range from 80 to 110 g for the dummy tests and are a little more scattered for cadavers : 80 g/3 ms for two subjects and 130 g/3 ms for the third subject, though the vehicle damage and crushing velocity at pelvis level were similar in the three tests ; this difference for the third subject can be accounted for by his lower weight.
Anyway, these values are of the same order of magnitude, both for dummies and cadavers and associated with an absence of injury for the three cadavers and the actual victims.
In 504/LN reconstructions, the pelvic accelerations were rather low both for dummy (between 60 and 75 g) and for cadavers (average 55 g).
In 504/504 reconstructions, the values of $\gamma$ 3 ms pelvis for the dummy are rather high : 100 and 120 g (only two tests).
For the cadavers, these values are around 100 g (lateral componant of the acceleration), so compatible with an absence of injury and compatible with those of the Hybrid II dummy tests.

For the MINI/CAPRI reconstructions with dummy, the values of $\gamma$pelvis are rather scattered (107, 121 and 169 g's).
For the cadaver tests, two subjects sustained a pelvis fracture, associated in one case, with a $\gamma$max of 114 g (no measurement in the other case) ; the third subject did not sustain any fracture, despite a comparable level of $\gamma$max (119 g) ; this difference in injury level was explained by a difference of age of the subjects, corresponding, a priori, to a higher bone resistance for the subject without fracture.
In the last reconstructions series (TAUNUS/PASSAT), the values of $\gamma$max pelvis for the dummy tests are also scattered (82, 141 and 98 g).
There is only one pelvis acceleration measurement in the cadaver tests ($\gamma$max = 135 g) ; no pelvis fracture was observed in the two tests performed, when the actual victim sustained a pelvis fracture (AIS = 3).
As a general conclusion, in the experimentations made, pelvic accelerations for the dummy are more scattered than with cadavers, especially in the two last reconstructions. However, despite this scattering, on an average, the same order of magnitude was found between dummy and cadavers, which would seem to indicate that the H II dummy and the cadavers act nearly similarly in lateral impacts, as concerns the pelvis accelerometric response. (The deformations of the side-wall at pelvis level are nearly identical for these two surrogates in the reconstructions).
For cadavers, the acceleration levels obtained for the pelvis corresponded (except in one special case) to an absence of pelvis injury ; in particular three 3 ms acceleration values were found, which were above 100 g (130, 118 and 105 g) ; far from invalidating the previously proposed tolerance threshold ( 3 ms = 100 g), these values would seem to indicate that the tolerance of living persons in lateral collisions may be higher.

## IV. COMPARISON OF RESULTS FROM THE KOB PROJECT WITH RESULTS OF OTHER PROJECTS

The main difference found between the KOB project and other projects, for instance FAT/HEIDELBERG study (6, 10) concerns medical findings for the cadavers.
A sample of 35 cadaver tests was analyzed by FAT/HEIDELBERG co-operation and it can be compared to the sample of 14 cadaver tests of the KOB project.
The test conditions were the following :

- striking vehicle : the MDB mounted on a sled (total mass 950 kg), at a velocity ranging from 40 to 60 km/h.
- struck vehicle : an OPEL KADETT body (same total mass 950 kg), which was at rest and impacted under an angle of 90°.

The main injuries found are the following :

- For the head : three skull fractures of AIS = 3 in HEIDELBERG sample among 35 cadaver tests and none in KOB sample where 14 cadaver tests were performed. These two results are comparable. This kind of injury is not frequent in actual lateral car to car collisions.
- For the thorax : the injuries obtained are mainly rib fractures (between 6 and 27), predominantly on the impacted side. That was also observed in the KOB sample.

- For the spinal column : one of the main differences between the two studies is at the level of this body segment. For FAT/HEIDELBERG sample, in two thirds of the cadaver tests, cervical spine column injuries appeared ; these were of minor or moderate severity, except in one case, where there was a most serious injury (AIS = 5), in a left side impact at 61 km/h.
  No such lesion was found in the KOB study. As there was no side windows for the car in Heidelberg study, and as there was no head impact during the collision, one may think that there was a large lateral bending of the neck, as indicated by the curves of head bending angles as a function of time, resulting in cervical spine injuries. The bending of the head was limited in our tests because occurrence of impact (except in one case).
- For the abdomen : in FAT/HEIDELBERG study, 17 out of 35 cadavers sustained internal abdominal injuries, when there were only two such injuries in the KOB tests.
  This is the main difference between these two studies, as regards cadavers injuries and these were the most severe injuries observed on these subjects. They generally consisted of liver ruptures, which predominantly occurred during 50 km/h lateral collisions, with impact of the occupants on the right side. In the three tests with a collision speed of 60 km/h, abdominal injuries occurred during left side impacts, consisting of injuries to the spleen, the left kidney and the liver.
  These tests were nevertheless performed at a violence either comparable or below that of the KOB reconstructed accidents as regards velocity of the striking vehicle ; so the difference of injury can only be explained by the differences in the test conditions.
  All the FAT/HEIDELBERG tests were performed with an angle of 90° between the two vehicles, which correspond to the most severe conditions (the two abdominal lesions in KOB reconstructions were also observed in 90° impacts). More, in the FAT/HEIDELBERG tests, the axis of the MBD was just in front of the H point (SR), so just in front of the pelvis and abdomen of the subject.
  This could be sufficient to explain the higher frequency of occurrence of abdominal injuries in these tests.
  These results of experimentations concerning abdominal injuries were compared to those of accidentological data. A sample of 14 cases of APR accidentological investigation, in which severe abdominal injuries (AIS $\geqslant$ 4) were present, could be gathered.
  Analysis of this sample pointed out the fact that spleen and liver injuries occur even if the impact a thorax and/or pelvis level is tolerable ; in 4 cases out of 14, the thoracic AIS was 0/1 and simultaneously the abdominal AIS was 4.
  In the same way, 6 cases out of 14 correspond to a thoracic AIS $\leqslant$ 2 (with AIS $\geqslant$ 4 for abdomen). These lesions were observed on occupants on the impacted side.
  So accidentological analysis also points out the necessity of using a specific abdominal criterion for protecting the abdominal area.*

---

* The same analysis on a greater sample of 23 cases with abdominal injuries (AIS $\geqslant$ 3) validating this result is published in a new paper (13).

- For the pelvis : the occurrence of injuries at this body segment differs few from one sample to the other ; such lesions were very rarely observed.

  The main conclusions of the FAT/HEIDELBERG study are globally in good agreement with those of the KOB project. Both studies show that the kinematics and loadings of dummies and cadavers are different in most of the body regions investigated.

  All tests for FAT/HEIDELBERG study were 90° side impacts, centered on H-point. It corresponds, according to HUK statistics, NHTSA/MVMA coordinated research project (11) and APR accidentological investigations (1), to the most severe lateral impact conditions.

## V. DISCUSSION AND CONSEQUENCES

### 1. Scatter on the results

Pre-tests were conducted in order to get the same deformation in the tests, as in the actual case. Therefore, in some cases, the collision speed, or angle, or impact point were modified as regards the estimations of the actual accident, the main reason being the difference in damage between the actual car and the car used in the reconstruction, which indicated that one or several parameters used for tse reconstructions was not satisfactory.
Inside a same reconstruction series, in some tests, the cadavers used were different from the actual victim, in particular for height, weight or age ; that is because the main selection criteria was based on the "good quality" of the subject, with no preexistant lesion. When there was a problem of height of the subject, a cushion was used, so as to try to reproduce the same torso and head heights as those of the actual victims.
Inside a same reconstruction series, the scatter is limited and is, in most cases, explained. For instance, as regards thorax injuries for the 304/R 15 collision, 13 rib fractures with a flail chest (AIS = 4) were sustained for the actual victim and :

- 20 rib fractures with flail chest (AIS = 4) for the first cadaver,
- 10 rib fractures (AIS = 3) for the second cadaver,
- 5 rib fractures and a collarbone fracture (AIS = 3) for the third cadaver.

Apart from the possible differences in the position and anthropometry of the subjects, these injury differences were accurately explained by the differences in bone conditions of these subjects. Therefore, the lesional levels sustained by the real victims and the cadavers proved to be very coherent.

### 2. Consequences of this research

- As regards impact tests, it would be interesting to compare systematically the extents and the shapes of the crushings obtained in lateral MDB/car collisions, with those obtained in lateral car to car collisions, for all available cases and try to rank them according to the different possible configurations.

  The knowledge of deformations of the side wall at the level of the main body segments (head, thorax, adbomen and pelvis), could enable to explain occurrence and severity or non-occurrence of injuries on the corresponding body segments, according to the kind of tests performed. Besides the stiffnesses of some parts of MDB could be adjusted for sake of realism.

The severity of actual lateral collisions for the occupant nearside the impacted wall, has to be assessed accurately, particularly by means of a complete analysis of the deformations of the passenger compartment. As a matter of fact, a rating of severity based only on car $\Delta$V values is not adequate. It is highly desirable that corrections on the estimations of the violence in terms of $\Delta$V could be made, taking into account the relative positions of the vehicles at impact (involvement of rigid parts, orientations of the cars...). We saw in these KOB selected cases, that accidents corresponding to $\Delta$V value of the same order of magnitude led to different injury severity levels. This points out the importance of the wall velocity on the severity of impacts (14).

- For the dummies used in the reconstructions, the necessity of a separate criterion for the abdomen was once more proved, taking into account mainly the FAT/HEIDELBERG results.
- As regards restraint systems, APR accidentological investigation indicates that "belt wearing reduces lateral accidents seriousness" (1).
  The wearing of a seat belt in lateral impact results in two main consequences that are the following : that of restraining the occupant on the struck side (so avoiding possible ejection and lowering its trajectory), and also that of reducing possible interactions with another adjacent passenger (who, in almost all cases is also belted).
  When there is only one belted occupant, the percentage of head lesions is reduced ; this can be attributed to the different kinematics of the belted occupant : lesser lateral flexion of the head/neck/shoulder segments towards the side window frame, this being the consequence of the fact that the shoulder and the pelvis are restrained. For instance, in the third cadaver test of 504/LN KOB reconstruction, the subject was unbelted and we observed a very special kinematics, corresponding in fact to a partial ejection of the subject (with very severe head and brain stem injuries AIS $\geq$4).
  Some restraint systems, specific for protection in lateral collisions -such as paddings- could be thought up.
  Up to now, one of the actions for ensuring protection of occupants in lateral impact consisted in rigidifying the struck door, with the aim of limiting the intrusion. Keeping the doors as they are and just adding a padding inside is another way, more rarely tried ; it could be interesting to duplicate for instance one of the KOB reconstructions with a modified car, according to what is said above (just with a padding inside) and compare with results of the previous reconstructions ; however, the problem of the spacing between the side wall and the body must be considered.

## CONCLUSIONS

- As a conclusion, damages to the struck and striking vehicles were correctly reproduced with reference to the real accidents. These KOB reconstructions were performed with a good general accuracy, which provides a satisfactory research tool based on actual collisions reconstructions.
  We got always satisfactory analysis of the differences of lesions for each reconstruction series when the differences of bone condition of the subjects were taken into account.

- For the head, none of the cadavers, except for a very peculiar 504/LN reconstruction, sustained cranial or cerebral injuries ; this absence of injuries corresponds to HIC values up to 1980 (the likelihood of such a value whithout injury was commented upon).
  This absence of injury is in good agreement with what was observed in the actual accidents : as a matter of fact, only two head injuries of an AIS level 2 were observed in these accidents.
- Taking into account the bone condition of the subjects, the lesional levels sustained by the real victims and the cadavers are very coherent at thorax level, when we use the thoracic deflection as assessment of injury severity.
- As regards pelvis, only few lesions were found and in particular the high values recorded for the pelvis accelerations would seem to indicate that the tolerance of living persons in side-collisions might be higher than 100 g/3 ms.
- Great differences were found between the PART 572 dummy and cadavers for all body segments, except for the pelvis, confirming that this dummy is unsuitable for use in side-collisions.
  A particular interest of the KOB program by comparison with FAT/HEIDELBERG study for instance, is that we dispose of a realistic reference : actual accidents, with all the informations both as regards the involved cars and the injuries sustained by the actual victims.
  A number of further utilizations of KOB data can be anticipated. For instance, they can be used for assessing the biofidelity of any dummy proposed for tests in lateral impacts ; two of them were already used for testing EUROSID dummy.

REFERENCES

(1) Side-impact Collisions - Accidentological Summary Report - PEUGEOT SA/RENAULT Laboratory of Physiology and Biomechanics - June 1983 (Referenced ISO TC22 SC10 - N° 69)

(2) D. OTTE and E.G. SUREN, HANNOVER - H. APPEL and J. NEHMZOW, T. U. BERLIN "Vehicle Parts Causing Injuries to Front-Seat Car Passengers in Lateral Impact" SAE Paper 84 1651, in 28th Stapp Car Crash Conference - CHICAGO, November 1984.

(3) C. GOT, A. PATEL, A. FAYON, C. TARRIERE, and G. WALFISCH "Results of Experimental Head Impacts on Cadavers - The Various Data obtained and their Relations to some measured Physical Parameters" SAE Paper 78 0887 in 22nd Stapp Car Crash Conference, Ann. Arbor, October 1978

(4) J. SACRESTE, F. BRUN-CASSAN, A. FAYON and C. TARRIERE, PEUGEOT SA/RENAULT - C. GOT and A. PATEL, IRO "Proposal for a Thorax Tolerance Level in Side-Impacts based on Tests performed with Cadavers having Known Bone Condition - SAE Paper 82 1157, in 26th Stapp Car Crash Conference - Ann Arbor, October 1982

(5) C. GOT, F. GUILLON, A. PATEL and P. MACK
F. BRUN-CASSAN, A. FAYON and C. TARRIERE "Morphological and Biomechanical Study of 146 Human Skulls used in Experimental Impacts in relation with the Observed Injuries" SAE Paper 83 1619, in 27th Stapp Car Crash Conference, SAN DIEGO, October 1983.

(6) G. KLAUS, R. SINNHUBER and G. HOFFMANN VW.AG - D. KALLIERIS and R. MATTERN, University of HEIDELBERG "Side-Impact - A comparison between Dummies and Cadavers. Correlations between Cadaver Loads and Injury Severity" SAE Paper 84 1655, in 28th Stapp Car Crash Conference, CHICAGO, November 1984.
(7) D.H. ROBBINS, R.J. LEHMAN, HSRI University of MICHIGAN, "Prediction of Thoracic Injuries as a Function of Occupant Kinematics", in Proceedings of the 7th ESV Conference, PARIS 1979.
(8) R.M. MORGAN and H.P. WATERS, NHTSA, U.S. Department of Transportation "Comparison of Two Promising Side-Impact Dummies", in Proceedings of the 8th ESV Conference, WOLFSBURG, October 1981.
(9) R.M. MORGAN, J.H. MARCUS and R.H. EPPINGER, NHTSA, U.S. Department of Transportation "Side Impact - The Biofidelity of NHTSA's Proposed ATD and Efficacy of TTI" in Proceedings of the 30th Stapp Car Crash Conference, WASHINGTON, 1986.
(10) G. KLAUS and D. KALLIERIS "Side-impact - A Comparison between HSRI, APROD and Hybrid II Dummies and Cadavers" SAE Paper 83 1630, in 27th Stapp Car Crash Conference, SAN-DIEGO, October 1983.
(11) Coordinated Research : "Report of the Accident Data Analysis, Task Force", September 1982.
(12) "CCMC Position on side impact protection" Presented at the NHTSA Hearing on Side Impact Protection", WASHINGTON D.C., 28/29 May 1986.
(13) F. BRUN-CASSAN, Y. PINCEMAILLE, P. MACK, C. TARRIERE "Contribution to the evaluation of the criteria proposed for thorax-abdomen protection in lateral impact", 11th ESV Conference - WASHINGTON - May 1987.
(14) C. THOMAS, C. HENRY, F. HARTEMANN, F. CHAMOUARD, C. TARRIERE "Injury Pattern and Parameters to assess severity for occupants involved in car to car lateral impacts". 11th ESV Conference, WASHINGTON, May 1987.