CAR SAFETY AND RATINGS : COMPARATIVE STUDY OF FACTS AND PRACTICES - PROPOSALS

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ABSTRACT

The existing specific test results obtained for rating purposes in Europe and the USA are compiled and analysed. These results represent the start of an interesting data bank allowing correlations between :

- . maximum average car deformation ;
- . average car deceleration ;
- . dummy measurements (driver and front passanger) ;
- . occupant compartment deformations.

They give the opportunity to make comparisons between various restraining systems, involving up-to-date technologies such as airbags, pretensioning systems, etc.
The meaning of the results is discussed, with reference to accident research and biomechanical knowledge.
An attempt to compare tests results and accident data available for the same cars allows convergences and divergences to be shown.
Proposals are presented in order to improve the quality of car safety assessment.

INTRODUCTION

With the increasing interest shown by the general public for road safety, attempts are being made to assess the protection afforded by cars when they first come onto the market. Because these are new cars, the assessment cannot be based on accident research, because it takes years to compile samples of the required minimum size. The approach we shall study here is therefore experimental, based on crash tests.
The first method is an American programme which started more than 15 years ago, known as the New Car Assessment Programme (NCAP).
The first method to appear in Europe was the programme of the Allgemeiner Deutsche Automobile Club (ADAC), with the Auto Motor und Sport (AMS) programme appearing more recently, in 1990.
Under the American test programme, it is considered that protection must be assessed in the most stringent deceleration conditions. The two European tests, on the other hand, are based rather on the assumption that severe and fatal injuries are associated with intrusion. For example, in a recent discussion on this subject Zetsche asserted that "75% of severe injuries are probably due to intrusion" (1).
What is the truth of the matter ?
It seems to us that two questions must be answered first :

- . What is the breakdown of responsibilities between the two causes, "acceleration" and "intrusion", mentioned with respect to injury risks for restrained motorists (the third cause, i.e. ejection, being eliminated by wearing the seat belt) ?

- For these two causes, whatever their relative weight, should a distinction be made between the required protection criteria (knowing that the test conditions would no doubt be different) ?

The answer to these questions should clarify the nature of the problems to be solved, placing the discussion on a scientific level and leading to simple, universally accepted rules, complied with by everyone, and thus improving the validity and credibility of attempts to rate cars according to the real protection afforded in an accident.

I - APPROPRIATE GUIDELINES FOR THE MOST EFFECTIVE PROTECTION OF VEHICLE OCCUPANTS CAN ONLY BE BASED ON THE ANALYSIS OF REAL WORLD CRASHES

I - 1. Definitions

A distinction can be made between two major families of injuries according to the conditions in which they are observed on the road. The distinction is between :

a) Accidents with very high acceleration levels in the passenger compartment : ah+ injuries.
b) Accidents with low levels of passenger compartment acceleration but in which local accelerations can be generated in certain areas of contact between some body segments and parts of the passenger compartment : ah- injuries, generally associated to intrusion inside the passenger compartment.

Example of type of injuries for these two families :
The ah+ injuries are typically thoracic injuries such as can be observed for the passengers in particular. The thorax makes no direct contact with the passenger compartment but the high passenger compartment accelerations generate major restraint force levels via the thoracic strap. This causes mainly fractures of the thoracic cage which may or may not be associated with internal thoracic injuries. For a given person, the forces applied to the thorax increase with the level of passenger compartment deceleration. It will already be clear that, all else being equal, the thoracic risk is higher when the car is less deformable, hence stiffer.
In exceptional cases, injury due solely to acceleration can be observed, without any direct impact on the body region concerned. The few examples that exist are brain concussion in high-speed frontal impacts involving restrained occupants. For example, in an impact against a rock at 73 km/h in Sweden, two child passengers in the back seat suffered a brief loss of consciousness of no severity. The deceleration at the passenger compartment level was 21 G on average and 58 G as a maximum value (2) .
The ah- injuries are observed mainly on the driver side in the event of major penetration of the passenger compartment by wall elements. The best and by far the most frequent illustration of this is the injury of the "kneecap-femur-pelvis" segment by front to rear movement of the dashboard at the knee level. The risk of fracture accordingly increases with the extent of this movement. These injuries are caused by intrusion. Usually, ah- injuries are related to severe frontal intrusion into the passenger compartment.

I - 2. Description of a representative sample of severe and fatal injuries (M.AIS 3+)

Source: . Detailed survey by the PSA-RENAULT Laboratory of Accident Research and Biomechanics covering 8,000 vehicles and 14,000 occupants.

. The study of 1,280 police reports on fatal accidents which occurred in France in the second quarter of 1990.
The results concerning overlaps are very similar to those published by Pete Thomas (Loughborough University in the UK) (3).

I -2.1. Typical real world illustrations of injury mechanisms according to ah+ and ah-

First example - Head-on Collision ah- :
HIGH INTRUSION RATE and LOW INJURY SEVERITY
In a head-on collision between two light cars with a slight overlap of about 50 % at a closing speed of about 100 km/h (figure 1) :
- the static intrusion of the dashboard reaches 59 cm in the case car;
- the driver, BELTED, 22 years old, received only minor injuries: AIS 2 (nose and left cubitus fractures);
- the front passenger sustained only a sternum fracture and a luxation of the left ankle.

It should be emphasized, as will be shown later at the statistical level, **that the driver sustained no foot or ankle injury despite the extent of foot panel intrusion.**
In the opposing car, the two front occupants, UNBELTED, sustained multiple fractures.

Second example - Head-on Collision ah+ :
NO INTRUSION and HIGH INJURY SEVERITY
In a head-on collision between two medium-sized cars with a large overlap (90 to 100%) at a closing speed of about 110 km/h, the female passenger, 62 years old, BELTED, suffered fatal injuries (figure 2) :
. a flail chest with aortic and pulmonary artery ruptures;
. spleen rupture;
. open fracture of the left ankle;
. dislocation of C2 C3 and cranium base fracture.

The driver, 63 years old, sustained a left clavicle fracture, 2nd, 3rd left rib fractures and right femur fracture.
In the opposing car, the driver, 38 years old, sustained a facial fracture (LEFORT II) due to a steering wheel impact.

Third example - Head-on Collision ah+ :
NO INTRUSION and HIGH INJURY SEVERITY
In a head-on collision between a large car and a medium-sized car at a closing speed of about 120 km/h, with a large 90% overlap (figure 3).
The female driver of the large car, BELTED with a pyrotechnic pretensioning belt, 48 years old, sustained facial haematoma, 4 rib fractures and complex multiple fractures on the right ankle and lower tibia (7 fractures).
Remark: Severe foot fractures without foot panel intrusion.
The driver of the medium-sized car, aged 22, and the front passenger, aged 19, both BELTED, also sustained multiple fractures of the legs.
Due to the mass ratio, the ΔV was about 50 km/h for the large car and 70 km/h for the medium-sized car.

Apart from certain special cases, the in-depth analysis of representative samples proves that the acceleration mechanism causes a greater number of severe and fatal injuries (M.AIS 3+) than the intrusion mechanism itself. This is clearly shown in the following chapter and in the paper presented by J.Y. Foret Bruno at the ESV Conference (Munich, May 1994) under the title "In depth analysis of frontal collisions as regards the influence of overlaps and intrusion on occupant severe and fatal injuries" (4).

I - 2.2. Observed overlaps and severity of restrained occupant injuries

The head-on car-to-car collision is the most representative, accounting for 49% of cases.
In head-on car-to-car collisions involving M.AIS 3+ BELTED FRONT OCCUPANTS:

- in 87% of cases, the front end overlaps are in the range between 10% left and 100%;
- the mean overlap is 64%, and the median is 69%;
- 63% of M.AIS 3+ (severe and fatal injuries) correspond to an overlap of between 60 and 100%.

Figure 1

Figure 2

Figure 3

Injury according to overlap :

The impacts with the strongest left-hand offset (< 40%) represent a majority of injuries of the "femur-pelvis" segment for drivers, while head injuries in particular are insignificant. In a more representative impact of overlap > 60%, on the other hand, the level of injuries to the head (25%), the thorax (25%) and the femur (26%) is the same.

For these overlap configurations, no severe injury is observed for restrained front passengers in the case of low overlap values. On the other hand, the severity is multiplied by nearly 20 for overlaps exceeding 60%. Nearly all injuries appear at the level of the thorax (50%) and abdomen (36%). The head ranks third, with 7% of AIS 3+ injuries.
A strongly offset impact therefore does not reflect the potential risks to front-seat passengers (5).

Conclusions concerning overlaps

The results of head-on collisions show that a representative test shall mandatorily:

- have a median overlap with the obstacle of 69% (and a collision angle of 13°);
- include two instrumented dummies on the front seats.

It would thus cover 65% of restrained driver/front passenger pairs with injuries of severity M.AIS 3+ involved in possible impacts to be reproduced by testing, i.e. impacts in which all the energy is dissipated against the obstacle.
TABLE I shows that our conclusions are very similar to those published by Pete Thomas (Loughborough University of Technology) in the Proceedings of the ISATA Conference - Aix La Chapelle - September 1993 (3).

TABLE I : COMPARISON OF FRONT-END OVERLAPS RECORDED IN TWO COUNTRIES FOR SEVERELY AND FATALLY INJURED FRONT BELTED OCCUPANTS

		Loughborough University of Technology (Pete Thomas)	L.A.B. PSA - RENAULT	
AGAINST CARS	Average Overlap			
	. M.AIS 3-4-5	70%	66%	(70%)*
	. Fatal	86%	72%	
	Overlap Frequencies			
	≤ 50% . M.AIS 3-4-5	34%	25%	(19%)*
	. Fatal	27%	20%	
	≤ 40% . M.AIS 3-4-5	22%	15%	(9%)*
	. Fatal	11%	16%	

* Without glance off

Knowing that the corresponding value for Hanover University is 57% (6), it appears that in Germany and the UK, as in France, the severely injured car occupants are involved in head-on accidents with a large average overlap ranging from 57% in Germany to 70% in the UK.
This result clearly indicates that high accelerations act at the passenger compartment level (ah+) and thereby contribute to severe occupant injuries.

I - 2.3. Intrusion and severity of restrained injuries

A rough evaluation of the severity (M.AIS 3+) according to the level of intrusion, without taking into account speed biases observed in each class, tends of course to show that severity is linked to the level of intrusion. Without correcting for speed biases, our results are of the same order.
It is therefore essential to correct this bias so as to obtain an equivalent speed distribution for each class of intrusion.

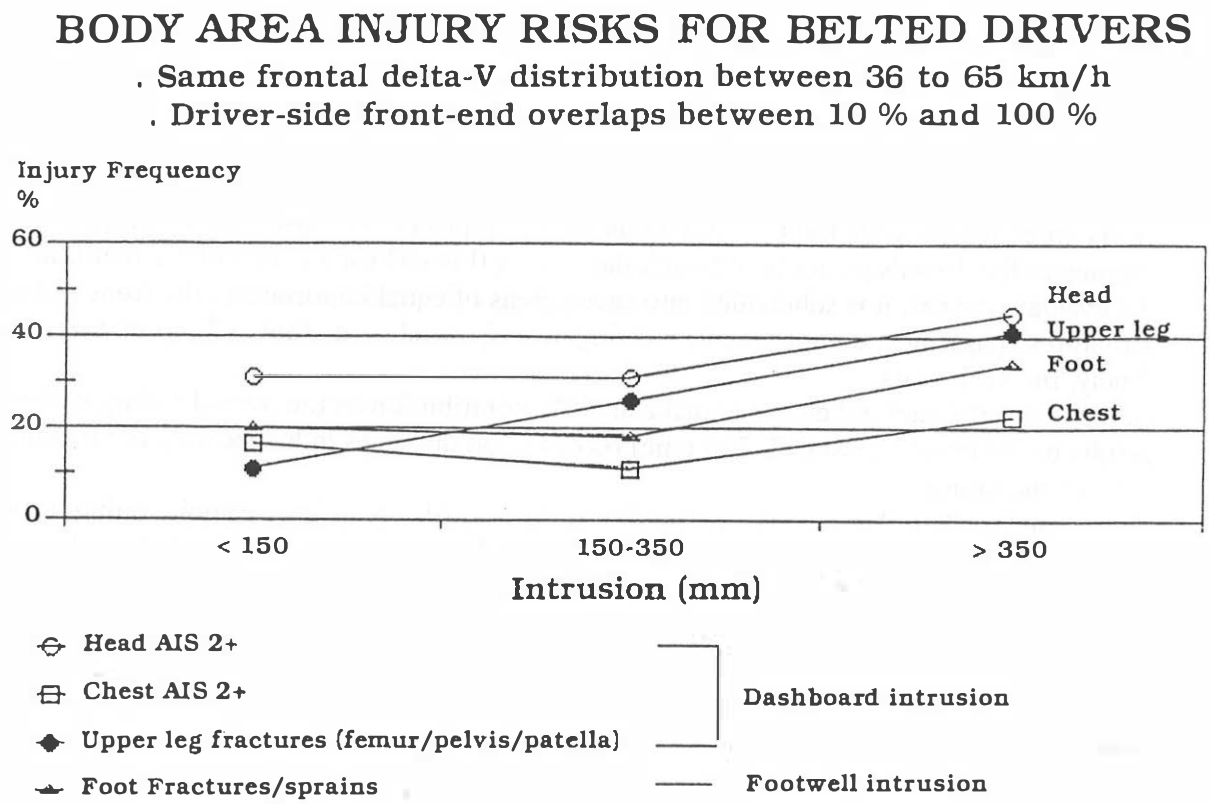
Injury severity for restrained drivers and intrusion

The very great majority of cases with intrusion occur on the driver side (83%). A selection was therefore made of 354 restrained drivers involved in impacts with overlaps in the range between 10% left and 100%, and for delta-V values in the range between 36 and 65 km/h. It appears that :

- below an intrusion of 15 cm, the injury severity and fatality rates are equivalent;
- for intrusions of 15 to 25 cm and 25 to 35 cm, injury severity increases but there is no change in the fatality rate;
- for strong intrusions (> 35 cm), the fatality rate increases significantly (4).

This increase in severity for the two intermediate classes is due chiefly to an increased risk of injuries to the knee/femur/pelvis segment, as can be seen in Figure 4. For the other body areas, there is no increase in risk below 35 cm of intrusion; one even observes a reduction in the risk of thoracic injuries for intrusion in the range between 15 and 35 cm.
Concerning foot injuries, one observes that for intrusions of less than 15 cm or between 15 and 35 cm, the risk is identical.

Figure 4



<u>Severity of restrained passenger injuries</u>

For left-offset frontal impacts, for an identical impact violence, the greater the intrusion on the driver side, the lower the risk for the passenger. Hence, injury severity ranges from 0.31 to 0.21 for driver side intrusion below and above 25 cm respectively, and the fatality rate from 0.07 to 0.

Deceleration is the main cause of injury (4).

II - COMPARISON BETWEEN PRESENT ATTEMPTS TO MAKE CAR SAFETY RATINGS AND THE GUIDELINES STIPULATED BY ACCIDENT RESEARCH.

There are three main experimental ratings of car secondary safety :

. The New Car Assessment Programme (NCAP), started in 1979 by the US National Highway Traffic Safety Administration to provide information for the consumers. Each year, a number of selected recent models are subjected to a test against a 0° angled wall at a speed of 55 km/h (35 mph). Measurements are performed on two Hybrid III dummies installed in the front seats. The criteria comply with those taken into account in regulation FMVSS 208, namely :
  - The Head Injury Criterion (HIC) must not exceed 1000.
  - The maximum thoracic acceleration for three milliseconds must remain below 60 g.
  - Finally, the forces measured in the femurs must not exceed 10,000 N.

These results are published in the press. In 1983, Jack Gillis produced a formula weighting these various criteria and providing a figure for relative car ratings. Since this year, a simplified reading system involving a number of stars is proposed for each of the criteria recorded on dummies (7).

. The ADAC in Germany has been carrying out crash tests since 1988 on series of recent cars of the same category, selected by itself. From the start, the cars have always been tested at a speed of 50 km/h in a left-offset frontal impact. The overlap between the car front and the barrier is 40%.

Two 18 kg loads are placed in the boot to simulate the luggage.

In the most recent tests, the Hybrid III dummy has replaced the earlier-generation Hybrid II dummy in the driver's position, although the Hybrid II is still used in one of the rear seats.

To evaluate the car, it is subdivided into seven areas of equal importance ; the front and rear structures, passenger compartment, steering wheel, dashboard, footwell, front seats and, finally, the back seats.

In the end, car structural elements make an 80% contribution to the overall rating, while the results of the criteria (FMVSS 208 type) recorded on dummies influence only the remaining 20% of the rating.

Note, finally, that the results are published in accordance with a simple rating (good, medium, bad) in the ADAC review. The results of the measurements recorded on dummies have now been published for the latest tests. In addition to this there are mostly certain specific values concerning structural deformation due either to dynamic forces (body acceleration, steering wheel movements) or static forces (intrusion of the A-pillar or deformation of the footwell, for example).

. The German motoring magazine AUTO MOTOR UND SPORT (AMS) set up its own test in 1990. This test differs from the previous one in various respects :

  - the front overlap of 50% with the barrier formed of a 15° slanting wall with anti-slide device ;
  - the speed, 56 km/h;
  - the two dummies, 50th percentile Hybrid II and more recently Hybrid III, both placed in the front.

Apart from the standard measurements performed on dummies, the angles of head rotation and the seat-belt forces are quantified.

The car deformations undergo various measurements concerning in particular movements of the steering wheel, the dashboard, the pedal assembly, the dash panel, the front pillar and the front wheels. The post-impact door opening forces are also taken into account.

These test results are published in the AMS review. The injury risks for each body area are evaluated on the basis of the biomechanical results, analysis of films and the deformation of the passenger compartment. Finally, the judgements concerning the risk incurred are classified in three categories (or colours): low, average or high.

In view of the obvious differences between the three tests mentioned above, the only comparisons we can make concern the "HIC, thoracic acceleration and femur force" values, i.e. the traditional criteria universally employed.

THE COMPARISONS BETWEEN NCAP, ADAC and AMS are given in TABLES II to IV.
The samples considered are the published results available.

. For the NCAP, there are two sources:

  - A publication by I. Hackney (8) concerning 126 tested cars from model years 1987 to 1991.
  - A recent article (9) listing the results for 72 cars from model year 1993.

TABLE II : HIC IN CAR CRASH TEST RATINGS

	DRIVER HIC							FRONT PASSENGER HIC						
	Mean	Standard deviation	<500	500 -999	1000 -1499	>1500	Number	Mean	Standard deviation	< 500	500 -999	1000 1499	>1500	Number
ADAC (60 km/h, 40 % rigid) (22 cars)	708	54	5 (23 %)	14 (64 %)	3 (13 %)	0 (0 %)	22 (1 airbag) 100 %	--	--	--	--	--	--	--
AMS (55 km/h, 50 % rigid) (32 cars) TOGETHER	879	352	4 (13 %)	17 (53 %)	10 (31 %)	1 (3 %)	32 (100 %)	567	287	15 (47 %)	16 (50 %)	1 (3 %)	0 (0 %)	32 (100 %)
WITH airbag	681	279	2	9	1	0	12	533	156	1	2	0	0	3
WITHOUT airbag	998	343	2	8	9	1	20	571	299	14	14	1	0	29
NCAP - MY 87-91 55 km/h 0° rigid (126 cars)	864	365	16 (13 %)	74 (60 %)	26 (21 %)	8 (6 %)	124* (100 %)	726	383	33 (28 %)	67 (57 %)	11 (10 %)	6 (5 %)	117* 100 %
NCAP - MY 93 55 km/h 0° rigid (72 cars) TOGETHER	700	281	15 (21 %)	50 (70 %)	5 (7 %)	1 (2 %)	71* (100 %)	673	221	18 (27 %)	44 (66 %)	5 (7 %)	0 (0 %)	67* (100 %)
WITH airbag	606	168	13	34	0	0	47	609	174	3	5	0	0	8
WITHOUT airbag	884	362	2	16	5	1	24	681	227	15	39	5	0	59

* Some results are not available.

TABLE III : "Acc. 3 ms THORAX " VALUES IN CAR CRASH TEST RATINGS

	Acc. 3 ms DRIVER								Acc. 3 ms FRONT PASSENGERS							
	Mean	Standard deviation	≤ 39	40 - 49	50 - 59	60 - 69	≥ 70	Number	Mean	Standard deviation	≤ 39	40 - 49	50 - 59	60 - 69	≥70	Number
ADAC (60 km/h, 40 % rigid)	42	10	9 (41 %)	9 (41 %)	4 (18 %)	(0 %)0	0 (0 %)	22 (100 %)	--	--	--	--	--	--	--	--
AMS (55km/h 50% rigid)	53	9	2 (6 %)	12 (38 %)	11 (34 %)	5 (16 %)	2 (6 %)	32 (100 %)	39	7	18 (56 %)	13 (41 %)	0 (0 %)	1 (3 %)	0 (0 %)	32 (100 %)
WITH airbag	55	11	1	4	3	2	2	12	43	3	0	3	0	0	0	3
WITHOUT airbag	52	7	1	8	8	3	0	20	38	7	18	10	0	1	0	29
NCAP - MY 87-91 55 km/h 0° rigid	49	8	14 (11 %)	50 (41 %)	47 (38 %)	11 (9 %)	1 (1 %)	123 (100 %)	43	7	35 (29 %)	67 (56 %)	15 (13 %)	0 (0 %)	2 (2 %)	119 (100 %)
NCAP - MY 93 (55 km/h, 0° rigid) TOGETHER	49	6	4 (6 %)	38 (53 %)	26 (37 %)	2 (3 %)	1 (1 %)	71 (100 %)	43	6	18 (26 %)	40 (57 %)	11 (16 %)	1 (1 %)	0 (0 %)	70 (100 %)
WITH airbag	48	6	4	24	18	1	0	47	46	7	1	3	4	0	0	8
WITHOUT airbag	50	7	0	14	8	1	1	24	43	7	17	37	7	1	0	62

TABLE IV : FEMUR FORCES IN CAR CRASH TEST RATINGS

	FEMUR FORCE - DRIVERS (N)								FEMUR FORCE - FRONT PASSENGERS (N)							
	LEFT				RIGHT				LEFT				RIGHT			
	Number	Mean	Standard deviation	> 10 000 N	Number	Mean	Standard deviation	> 10 000 N	Number	Mean	Standard deviation	> 10 000 N	Number	Mean	Standard deviation	> 10 000 N
ADAC (1)	19	3 200	1 300	0	?	?	?	?	0	--	--	--	0	--	--	--
AMS (2)	31	5 077	3 127	2	?	?	?	?	18	2723	1316	0	?	?	?	?
NCAP cars MY 87-91	120	4 560	540	2	122	4 810	2 000	0	119	3770	1871	0	120	3230	1900	1

(1) A single "femur" result recorded in the ADAC impacts, with no indication of the side, arbitrarily shown on the left in the table (reminder : no front passenger).
(2) A single "femur" result for the driver and front passenger in the AMS tests, arbitrarily shown here on the left in the table. In fact this is THE HIGHEST VALUE.

. For the ADAC and AMS, the biomechanical values are available to the public and are published for 22 and 32 cars respectively.
A distinction is made between data with and without airbag, except for ADAC (only one car out of 22).

The comparison shows that:

. The ADAC test, which is comparable with the two others for drivers without airbag, gives consistently lower average values for each of the following three criteria :

head:	ADAC: 708	AMS: 998	NCAP: 884
γ thorax :	ADAC: 42 g	AMS: 52 g	NCAP: 50 g
max. femur force:	ADAC: 3200 N	AMS: 5077 N	NCAP: 4810 N

Moreover, the ADAC tests seldom show values exceeding the commonly accepted values measured on dummies. Out of 22 "ADAC driver-dummies", only three HIC values exceeded 1000, as against one quarter of the cases in the NCAP tests and half for AMS.
The "60 g on the thorax" level is never exceeded in 22 cases for ADAC, versus 10% to 15% of cases for NCAP and AMS.
The value of 10,000 N on the femur is never reached in an ADAC impact test, whereas it is exceeded in two cases both in the AMS and the NCAP impact tests (sample of cars from model years between 1987 and 1991).
In the end, the ADAC test does not make it possible to discern car safety from the criteria recorded on the driver-dummy due to the low force level reached. Understandably, then, car deformation must be used as a basis to try to amplify the slight differences recorded. This procedure seems very questionable, since it is not correlated to the data recorded on the driver-dummy.

. The AMS test seems intrinsically more relevant in its procedure. The levels reached by the measurements for the three criteria are of the same order as those recorded in the NCAP test at the same speed; however, without an airbag, the "AMS drivers" show average HIC values (+ 114) and femur force values (+ 517 N) slightly higher than those observed in the NCAP test in the same conditions. This must logically be attributed to the adverse influence of intrusion due to the asymmetry of the AMS test. The corollary of this is, of course, the weaker acceleration sustained by the front-seat passengers without airbag in the AMS tests, where the average values for each of the three criteria are low, less than those recorded in the NCAP tests in the same conditions (HIC: 110 less; γ thorax: 5 g less; femur force: 1047 N less).

. The NCAP test is "typical" of acceleration and ignores intrusion, while the AMS test is typical of the contrary. Both reflect only very imperfectly the less clear-cut situation observed in real-world accidents. Each of the tests is accordingly "extremist", because it accounts for only a single facet of the risk actually incurred by the users.

III. EVALUATION OF THE ROLE OF THE DRIVER AIRBAG

The results published by AMS make it possible, for the first time in Europe, to compare the results obtained with and without airbag on a sample of recent cars. In fact, two AMS sub-samples must be analysed depending on whether Hybrid II dummies or more recently Hybrid III dummies have been used. Two probably correlated criteria are not available: the HIC and the resultant head acceleration (A 3 ms).
Although the standard deviations are very high for the HIC (between 190 and 335), the average values are very significantly lower for the tests with airbags. For example, the values are 27% lower for the series with Hybrid III dummies, which can be compared with the 31% reduction obtained in the NCAP tests with the same dummy (TABLE V). This HIC reduction could be compared with a 24% reduction of the injury risk (mainly to the head) observed in

real-world accidents by several American authors compared with the risk sustained by the driver wearing a 3-point seat belt. It is interesting to note that for both the driver and passenger, the thoracic acceleration measured in the AMS and NCAP tests is not influenced by airbags (TABLE III).

TABLE V : AMS DATA BANK, HYBRID II DRIVER
EVALUATION OF THE ROLE OF THE DRIVER AIRBAG

	AIRBAG H2	STEERING WHEEL H2	AIRBAG H3	STEERING WHEEL H3
MEAN HIC	697.73	1,002.25	614.80	836.75
Std deviation	286.54	335.35	190.14	267.49
MEAN A 3 ms	70.18	87.60	73.40	80.25
Std deviation	14.34	17.80	17.62	*19.30

* Only this difference is not statistically significant (≥ 05). Source: AMS

EVALUATION OF THE ROLE OF PRETENSIONING SYSTEMS

The trend to widespread use of pretensioning systems is still too recent to allow them to be analysed in the same way as airbags.

IV - PROPOSALS

. Severe and fatal injuries (M.AIS 3+) sustained by passengers due to intrusion are seldom observed.

. Half of the driver injuries observed result from passenger compartment acceleration, and half from intrusion. 63% of all these injuries correspond to impacts with a high overlap exceeding 60% (median 69%).

. Whatever the type of injury mechanism, only the criteria measured on dummies can allow precise, objective evaluation of injury risks.

Interpretation of head risk

Driver : The HIC obtained with an airbag is on average far lower than that without an airbag. These very significant differences justify the claim that the sole presence of the airbag decreases the risk of severe head injury.

In the absence of an airbag, a HIC difference must be greater than the Minimum Interval to be able to assert that one car is different from another with respect to head/steering wheel impact. A Minimum Interval of 200 seems reasonable to allow for the scatter observed in the tests (10). The need to define a range of values for assessing car safety by body region is new [see M. MACKAY - 33rd AAAM Conference Proceedings (11)].

Moreover, it may be questioned whether HIC values should be determined in order to represent the limits of appearance of head injuries of varying degrees of severity. But the HIC can be considered as an indicator of impact violence allowing a distinction to be made between head impacts of low violence (HIC < 800), of moderate violence (800 < HIC < 1200) and of severe violence (HIC > 1200).

However, no particular HIC value should be associated with a severe or fatal injury, since experiments with human subjects have shown the absence of visible brain injuries associated with HIC values of 2500 for example. AMS uses colours to classify the severity of head impact. Why not ?

- Green would accordingly be associated with HIC < 800
- Orange would be between 800 and 1200

- Red for HIC values above 1200, with shades of colours to indicate that clear limits would be arbitrary.

Interpretation of cervical risk

The measurement tool is available on the Hybrid III dummy. It enables an objective assessment to be made, eliminating any subjective estimations based, for example, on the measurement of angles.

Interpretation of thoracic risk

So long as thoracic acceleration is still used, we propose also taking into account a Minimum Interval equivalent to that for the HIC, i.e. equal to two standard deviations. The same source as before gives MI = 8 for the driver and MI = 4 for the passenger (10).
Our proposal is that in the future the thoracic risk should preferably be evaluated with the thoracic deflection.

Interpretation of abdominal risk

It is proposed to evaluate the risk of submarining using the tools now available (12). There is a critical need for this, since this risk represent a large proportion of the overall risk, especially for the passengers (23% of the risk for the front-seat passenger).

Interpretation of leg risk

Risk evaluation for the "kneecap-femur-pelvis" segment can be performed satisfactorily by measuring the forces passing through the femur. This is probably the evaluation which poses the fewest problems, with a well defined limit of fracture appearance at around 10,000 N. This is also the value which can vary most from one test to another. For a given car, the overall result depends on the stiffness of the area impacted by the knee (MI = 4000).
At present, we do not know what would be the most appropriate criterion for evaluating the risk for the feet and ankles. Research is in progress (4) (13). However, in the absence of satisfactory criteria, caution is needed, especially in interpreting floor deformation on the foot side, since based on accident research analysis, an extra risk can be spoken of only beyond a foot level intrusion greater than 35 cm. Below this limit, cars should be considered equivalent with respect to this body segment.
ADAC and AMS should therefore be careful that, by giving priority to the criteria of least deformation, they do not detract from the real protection afforded to the occupants, especially in the more severe accident conditions in which the great majority of severe injuries and fatalities are observed, i.e. frontal impacts with high overlap.
It is evident that in the strongly offset impacts of the ADAC (40% overlap), all the dummy criteria are complied with even by the stiffest car. This is no longer true in an AMS impact (50% overlap), in which the stiffest cars already reach their design limits, since four cars exceed the limits of American Standard 208 for the two most important criteria, namely the head and thorax.
It can well be imagined, therefore, that in frontal impacts with high overlap, the "dummy" performance would be even higher, especially at the thoracic level where the stresses exerted are directly related to the average deceleration of the passenger compartment.
Hence the interest of the draft European regulation for 1995. By requiring that the car makers meet the dummy protection criteria in an impact configuration which is asymmetrical (30° slanting barrier) but produces a 100% overlap, this regulation will cover the most dangerous situations, those in which most severe injuries and fatalities are observed.
However the requirements laid down by any more severe regulation may have a negative aspect. By trying to improve the level of protection on all models irrespective of their size and weight, there is a risk that the aggressiveness of the heaviest vehicles may be further increased.

This is quite a different matter, left aside in this paper but discussed specifically elsewhere (14). The proposal is therefore to monitor an anti-aggressiveness criterion while at the same time evaluating protection in frontal impact.

GENERAL CONCLUSIONS

1. One of the major criticisms made of attempts at car safety ratings is that they claim to distinguish between car A and car B on the basis of a single test. Two facts must be considered. First, there is the disparity inherent in crash tests. For a given model, the coefficients of variation range between 10% for a parameter regarded as highly repetitive (e.g., thoracic acceleration) and 30% for a parameter with great scatter such as the femur forces or rising of the steering wheel. The HIC would be a parameter with average scatter (of approximately 10 to 20%). This problem of scatter can be allowed for by adopting a Minimum Interval of two standard deviations within which two cars cannot be said to be different.
   The second fact is more complex. A single test is inadequate to determine the quality of protection provided by a model. For example, there are numerous frontal configurations in road accidents, and several frontal tests are needed to account for them. If a single test is performed, it is logical to select one that is as representative as possible of the road impacts causing the most severe and fatal injuries. This means using the M.AIS 3+ indicator, and the test must be asymmetric with a high overlap, greater than 66%.
2. The other major criticism concerns the subjectiveness of certain evaluations. The answer is to use dummy criteria for which the relationship with the injury risk is more clearly established than for any other criterion based on vehicle deformation. The evaluation should be based mainly on the measurements which are possible on Hybrid III dummies: HIC, cervical forces and moments, thoracic deflection and forces measured on the thoracic strap, non-submarining criterion, femur force, etc., and, as soon as possible, criteria for the feet and ankles.
   In short, the evaluation of car safety is a complex and difficult task, and the interpretation must take into account the limits inherent in the very means of evaluation.
   Some interpretations are incomplete, as is the case of the NCAP which completely ignores the abdominal risk in frontal impact. Other interpretations are arbitrary, being based on criteria in which the relation with the injury risk is not clearly established. The dissemination of such interpretations to the general public can even represent complete misinformation. Scientific researchers have the duty of analysing certain practices critically and thus helping the media to do their work better. At least NCAP, the first organization to try establishing safety ratings, has the merit of basing its rankings on a clearly understandable method excluding any arbitrary interpretations; the score for the cars tested is based solely on head and thoracic accelerations combined according to weighting factors.
   This paper is an effort to present reflections based on the results available. The proposals made are themselves subject to critical analysis. One objective for the scientific community concerned could be to define **a charter of recommendations** whose application would lead to an improvement in the quality of assessments made available to the general public.

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