

HEAD AND NECK INJURIES FOR BELTED FRONT OCCUPANTS INVOLVED

IN REAL FRONTAL CRASHES : PATTERNS AND RISKS

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ABSTRACT

Protection criteria for the head and neck to be measured on dummies are still discussed today on the basis of cadaver tests, boxers and volunteers.

But the statistical pattern of head and neck injuries and the risk evaluation for front belted occupants can only be described on the basis of frontal real-world accident investigation.

The sub-sample selected from the APR file contains 959 front occupants restrained by 3-point retractor belt including 654 drivers and 305 right front passengers.

The 275 head injuries and 102 neck injuries observed are related to violence of impact and areas contacted.

A complete medical description and injury mechanism are provided.

INTRODUCTION

In the field of road safety, seatbelt wearing is the most effective form of protection, greatly reducing the risk of severe and fatal injuries, and of facial and cranio-cerebral injuries in particular.

However, in the event of violent frontal impacts, seatbelts cannot prevent front occupants' head contact and this remains one of the main causes of injury risk to the belted front occupants.

Various samples of restrained occupants in frontal impacts have been studied. Some authors (1, 2, 3) have particularly analysed the frequency of facial impacts and of brief unconsciousness. Other authors (4, 5) have studied the risk of neck injuries of AIS 1 level without head impact. This study aims at determining, with the maximum precision, the frequency and gravity of head and neck injuries for front seat occupants restrained by retractor seatbelts involved in frontal impacts.

I - DESCRIPTION OF THE SAMPLE

Since 1970, 6,605 cars and their 12,580 occupants involved in real world impacts have been analysed by PEUGEOT S.A./RENAULT multidisciplinary investigation team.

For the purpose of this study a sample has been extracted with all the drivers and right front passengers restrained by 3-point retractor belts involved in single frontal impacts.

It contains 959 occupants in 684 cars, 654 drivers and 305 right front passengers.

I - 1. GENERAL CRASH CONDITIONS FOR THE SAMPLE CARS

The 684 cars have impacted others cars in 77 % of cases, fixed obstacles in 13 % and trucks in 10 %.

The deformations observed on the front end of cars are similar to those obtained in tests against a 30° barrier (or offset impacts with an overlap of half vehicle) for 49.8 % of the cases and to those obtained in offset impacts with an overlap of one third to a quarter in 28.8 %.

An equivalent test procedure of distributed 0° barrier covers 19.4 % and a centered pole test 1.9 % of cases.

The violence of impacts, in terms of speed variation (ΔV) and mean acceleration (\bar{a}) has been calculated for 537 cars.

For 38 % of them ΔV is higher than 35 kph, and for 9.7 % higher than 55 kph. Mean acceleration is higher than 12 g in 7.8 % of cases.

I - 2. GENERAL CRASH CONDITIONS FOR OCCUPANTS

The principal direction of forces is at 12 o'clock for 81.4 % of all the front occupants.

The impact violences (ΔV and \bar{a}) are quite similar for drivers and R.F. passengers (table 1).

The overall severity is evaluated by using M.AIS according to AIS 80 scale (6). For the 959 front occupants, there are 82 severely injured and 28 killed (table 2).

For drivers, mortality rate is of 3.2 and gravity rate of 11.0. The corresponding values for R.F. passengers are respectively 2.3 and 12.5.

The severity of injuries by body region (AIS) is known for 634 drivers and 299 R.F. passengers (table 3).

14 % of drivers and 10 % of R.F. passengers sustained injuries of AIS ≥ 2 level, to the head. These frequencies are lesser for the neck injuries, 0.6 % for the drivers, and 2% for the passengers.

TABLE 1 : DISTRIBUTION OF DELTA-V AND MEAN ACCELERATION
FOR FRONT OCCUPANTS IN THE SAMPLE
Delta-V (Kph)

		<u>≤15</u>	<u>16-25</u>	<u>26-35</u>	<u>36-45</u>	<u>46-55</u>	<u>56-65</u>	<u>>65</u>	<u>TOTAL</u>
Drivers	N	14	156	152	95	47	36	14	514
	%	2.7	30.4	29.6	18.5	9.1	7.0	2.7	100
R.F. Passengers	N	7	72	71	47	28	19	7	251
	%	2.8	28.7	28.3	18.6	11.2	7.6	2.8	100

Mean acceleration (g)

		<u>≤ 4</u>	<u>5 - 8</u>	<u>9 - 12</u>	<u>13 - 16</u>	<u>>16</u>	<u>TOTAL</u>
Drivers	N	94	259	122	33	6	514
	%	18.3	50.4	23.7	6.4	1.2	100
R.F. Passengers	N	41	127	64	15	4	251
	%	16.3	50.6	25.5	6.0	1.6	100

TABLE 2 : DISTRIBUTION OF FRONT SEAT OCCUPANTS BY INJURY
SEVERITY (M.AIS)
M.AIS

		<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>FATAL</u>	<u>TOTAL</u>
DRIVERS	N	264	205	113	46	4	1	21	654
	%	40.4	31.3	17.3	7.0	0.6	0.2	3.2	100

R.F. Passengers	N	107	117	43	21	9	1	7	305
	%	35.1	38.4	14.1	6.9	3.0	0.3	2.2	100

TOTAL	N	371	322	156	67	13	2	28	959
	%	38.7	49.8		8.6			2.9	100

II - HEAD INJURIES

II - 1. ANATOMICAL DEFINITIONS

We used the following definitions :

- Cranium :

- Frontal, temporal, parietal and occipital bones.
- Soft tissues in regard to these bones, i.e which are situated above an horizontal line running just above the eyebrows, including the forehead.

- Brain :

- Brain stem, cerebellum, cerebrum.

- Face :

- Ethmoid, sphenoid, nose, mandible, maxilla, orbit, zygoma, hard palate, temporo-mandibular joint.
- Soft tissues situated under the horizontal line previously defined (including eyebrows), mouth and teeth.

II - 2. FREQUENCY AND SEVERITY OF HEAD INJURIES

Firstly, 67 % of drivers and 79 % of R.F. passengers do not have any injury to the head (table 3).

Considering the injuries of $AIS \geq 2$, the head is the most frequently injured of all body regions for drivers and for R.F. passengers.

For the injuries of $AIS \geq 3$ level the head is in the second rank order for drivers, and in the third for R.F. passengers.

II - 3. LOCATION OF HEAD INJURIES

Brain injuries of $AIS \geq 2$ are the most frequent for the drivers (10.6 %) and the R.F. passengers (9.0 %).

Severe brain injuries ($AIS \geq 3$) are four times more frequent for drivers than for passengers.

Facial injuries ($AIS \geq 2$ and also $AIS \geq 3$) are distinctly more frequent than cranial injuries.

One will see later (in chapter II - 6.) that brain injuries are generally associated to facial injuries and consecutive to a purely facial impact for the drivers, and associated to cranial injuries by purely cranial impact for the R.F. passengers.

**TABLE 3 : DISTRIBUTION OF AIS BY BODY REGION
IN THE SAMPLE**

A - DRIVERS

		<u>AIS</u>						
		<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>TOTAL</u>
HEAD		422	123	74	14	-	1	634

OF*	SKULL	532	98	4	-	-	-	634
WHICH	BRAIN	567	-	59	7	-	1	634
	FACE	492	110	24	8	-	-	634

NECK		571	59	2	1	1	-	634
CHEST		472	136	23	2	1	-	634
UPPER MEMBERS		519	78	26	11	-	-	634
D.L. SPINE		607	21	6	-	-	-	634
PELVIS		600	23	5	6	-	-	634
ABDOMEN		603	22	3	3	2	1	634
LOWER MEMBERS		450	119	39	26	-	-	634

B - R.F. PASSENGERS

		<u>AIS</u>						
		<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>TOTAL</u>
HEAD		236	33	23	7	-	-	299

OF*	SKULL	256	41	-	2	-	-	299
WHICH	BRAIN	272	-	26	1	-	-	299
	FACE	273	19	3	4	-	-	299

NECK		260	33	4	2	-	-	299
CHEST		178	95	16	4	6	-	299
UPPER MEMBERS		234	41	17	7	-	-	299
D.L. SPINE		276	16	5	2	-	-	299
PELVIS		283	13	-	3	-	-	299
ABDOMEN		273	14	1	4	5	2	299
LOWER MEMBERS		223	59	11	6	-	-	299

* INJURIES AT SKULL, BRAIN AND FACE CAN BE ASSOCIATED

II - 4. HEAD INJURIES AND SPEED VARIATION (DELTA-V) (table 4)

For impacts with delta-V below 56 kph (92 % of drivers and 91 % of R.F. passengers), about one third (29 %) of drivers sustained a head contact resulting in an injury of $AIS \geq 1$. Head contact with $AIS \geq 2$ injuries are observed in 10 % of the cases. For the R.F. passengers, there is head contact in 16 % of cases ($AIS \geq 1$) and a contact resulting in an injury of $AIS \geq 2$ in 6 %.

For impacts with delta-V higher than 55 kph (8 % of drivers and 9 % of passengers), head contacts are distinctly more frequent and the severity of resulting injuries is higher.

So 90 % of drivers sustained a head impact, associated with $AIS \geq 2$ injuries in 63 % of cases.

For R.F. passengers these frequencies are a little lower : head impacts in 65 % and contact with injuries of $AIS \geq 2$ for 52 % of cases.

Considering all the front occupants with a head injury of $AIS \geq 1$ (N = 223) one can say that only 2 of them suffer from a single brain injury without head contact, these are AIS 2 injuries for two R.F. passengers.

II - 5. AREAS CONTACTED BY THE HEAD (table 5)

67 % of drivers do not contact anything, neither do they sustain any lesions. When a contact occurs and when the area can be identified the steering wheel is struck in the majority of cases, 87 % for all lesions and 67 % for the $AIS \geq 3$ injuries.

It is often difficult to determine with accuracy the steering wheel zone impacted by the head. Generally speaking, the steering wheel's aggressive zone is limited to the areas immediately surrounding the hub. The structure of the rim, the nature of the joint between rim and spoke and the position of the spokes can also influence the severity of head/steering wheel impact.

For R.F. passengers there is no contact or lesion in 79 % of cases. Out of all identified contact areas, the facia came distinctly at the top of the list with 78 % of all injuries and 67 % of $AIS \geq 3$ injuries.

Two passengers suffer from a minor brain lesion (unconsciousness < 15') without indication of head or neck contact. For the first one, among other injuries, he sustains a flail chest which could be the cause of unconsciousness. For the other one, an impact head against head with a rear passenger cannot be excluded.

II - 6. IMPACT SITES ON HEAD, AND TYPOLOGY OF INJURIES

In this chapter, one divides the impact sites on the head into three categories, according to our anatomical definitions. Cranial when only the cranium was impacted, facial when only the face was impacted and cranio-facial when both areas are impacted.

A - For the drivers (table 6 - A), considering all severity of injuries, the facial impacts are the more frequent (51.9 %).

They produce soft tissue injuries associated, or not, with facial bone fractures, and brain lesions.

The cranial impacts observed in 33 % of cases produced soft tissue injuries, with, or without, brain lesions, but without cranium fracture.

TABLE 4 : FREQUENCY AND SEVERITY OF HEAD INJURIES BY SEATING POSITION, HEAD CONTACT AND SPEED VARIATION (Δv)

A - DRIVERS

	<u>DELTA - V (Kph)</u>						<u>TOTAL</u>
	<u>≤ 25</u>	<u>26-35</u>	<u>36-45</u>	<u>46-55</u>	<u>56-65</u>	<u>> 65</u>	
<u>AIS HEAD</u>							
<u>WITHOUT HEAD</u>							
<u>CONTACT</u>							
AIS 0	159	118	40	10	4	0	331
<u>WITH HEAD</u>							
<u>CONTACT</u>							
AIS 0	-	-	1	-	1	-	2
AIS 1	8	30	29	22	9	1	99
AIS 2	3	4	24	12	13	5	61
AIS 3	-	-	1	2	5	2	10
AIS 4	-	-	-	-	-	-	-
AIS 5	-	-	-	-	1	-	1
TOTAL	11	34	55	36	29	8	173

B - R.F. PASSENGERS

	<u>DELTA - V (Kph)</u>						<u>TOTAL</u>
	<u>≤ 25</u>	<u>26-35</u>	<u>36-45</u>	<u>46-55</u>	<u>56-65</u>	<u>> 65</u>	
<u>AIS HEAD</u>							
<u>WITHOUT HEAD</u>							
<u>CONTACT</u>							
AIS 0	75	62	38	12	7	1	195
AIS 2	1	-	-	1	-	-	2
TOTAL	76	62	38	13	7	1	197
<u>WITH HEAD</u>							
<u>CONTACT</u>							
AIS 0	-	-	-	-	-	-	0
AIS 1	3	7	4	8	3	-	25
AIS 2	-	2	3	5	6	3	19
AIS 3	-	-	1	1	2	1	5
AIS 4	-	-	-	-	-	-	0
AIS 5	-	-	-	-	-	-	0
TOTAL	3	9	8	14	11	4	49

TABLE 5 : AREAS CONTACTED BY HEAD ACCORDING TO SEATING POSITION AND INJURY SEVERITY

A - DRIVERS (N = 634)

	<u>AIS HEAD</u>						<u>TOTAL</u>	<u>%</u>
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>		
STEERING WHEEL	— 3	83	54	9	0	1*	150	87.2
FACIA	— 0	3	4	2	0	0	9	
WINDSHIELD/ GLASSING	— 0	1	3	1	0	0	5	2.9
WINDSHIELD MOLDING	— 0	1	1	0	0	0	2	
EXTERIOR OBJECTS	— 0	0	0	2	0	0	2	1.2
OTHERS	— 0	3	1	0	0	0	4	2.3

UNKNOWN	0	32	11	0	0	0	43	

NO HEAD CONTACT	419	0	0	0	0	0	419	

TOTAL	422	123	74	14	0	1	<u>634</u>	

(* NO FATAL INJURY)

B - R.F. PASSENGERS (N = 299)

	<u>AIS HEAD</u>						<u>TOTAL</u>	<u>%</u>
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>		
FACIA	— 0	7	10	4	0	0	21	77.8
WINDSHIELD MOLDING	— 0	0	0	2	0	0	2	
WINDSHIELD/ GLASSING	— 0	2	0	0	0	0	2	7.4
EXTERIOR OBJECTS	— 0	1	0	0	0	0	1	
OTHERS	— 0	1	0	0	0	0	1	3.7

UNKNOWN	0	22	11	1	0	0	34	

NO HEAD CONTACT	236	0	2	0	0	0	238	

TOTAL	236	33	23	7	0	0	<u>299</u>	

the cranio facial association is found in only 15.1 % of cases. Considering only the AIS \geq 2 lesions the same order is observed, facial impacts (58.4 %) then cranial (22.5 %) and cranio facial (19.1 %) (see table 6 - B).

There are 52 cases of AIS \geq 2 by facial impacts, in 50 % of these cases there are fractures of facial bones of AIS \geq 2 (with or without brain injuries), and in 65.5 % there are brain injuries (with or without bone fractures of AIS \geq 2). Almost all the AIS \geq 2 of cranial impacts are due to brain injuries (19 out of 20).

When the impact is cranio-facial, the majority of AIS \geq 2 lesions are brain injuries (14 out of 17).

Only one driver sustains a cranium bone fracture (simple fracture of temporal : AIS 2) against 35 who suffer fractures of one or more facial bones. 4 are single nose fractures of AIS 1. The 31 other ones are nasal fractures of AIS 2, simples or complex fractures of mandible, maxilla, orbit or zygoma of AIS 2-3.

- B - For the R.F. passengers (table 7-A) considering all severity of injuries one see that cranial impacts are the most frequent (57.4 %) they induce in most cases soft tissue injuries, associated or not, with brain injuries. Facial impacts account for 29.5 % of cases and cranio facial ones for 13.1 %.

The same order is found for injuries of AIS \geq 2 (table 7 - B).

Firstly, cranial impacts for 46.7 %, then facial ones for 36.7 % and cranio facial for 10 %.

Two cases (6.7 %) of brain injuries without head contact are observed (AIS 2).

When cranial impacts occurred the AIS \geq 2 injuries are in most cases brain lesions (13 out of 14).

For facial impacts the most frequent injuries of AIS \geq 2 are brain lesions (9 out of 11) and facial bone fractures (6 out of 11).

Two passengers sustained cranium bone fractures (displaced frontal bone fractures of AIS 3) against 8 who are suffering from fractures of one or more facial bones. One case of simple nasal fracture (AIS 1) and 7 cases of simple or complex bone fractures of AIS 2-3.

TABLE 6: IMPACT SITES ON HEAD AND TYPOLOGY OF INJURIES FOR DRIVERS

A - ALL SEVERITIES (AIS \geq 1)

IMPACT SITES	INJURIES TYPOLOGY				TOTAL
	SOFT TISSUE	SOFT TISSUE + BONE	SOFT TISSUE + BRAIN	SOFT TISSUE + BONE + BRAIN	
CRANIAL	51	-	19	-	70
FACIAL	56	20	25	9	110
CRANIO-FACIAL	15	3	10	4	32
	122	23	54	13	212

B - MODERATE AND SEVERE INJURIES (AIS \geq 2)

IMPACT SITES	INJURIES TYPOLOGY						TOTAL
	SOFT TISSUE	BONE	BRAIN	BONE + BRAIN	SOFT TISSUE + BRAIN	SOFT TISSUE + BONE + BRAIN	
CRANIAL	1	-	19 ₍₂₎	-	-	-	20
FACIAL	-	18	25 ₍₁₎	8 ₍₁₎	1	-	52
CRANIO-FACIAL	1 (cranium)	2 (face)	9 ₍₂₎	4 ₍₂₎ (3 faces) (1 cranium)	1 (cranium)	-	17
	2	20	53	12	2	-	89

(x) of which AIS BRAIN \geq 3

TABLE 7: IMPACT SITES ON HEAD AND TYPOLOGY OF INJURIES FOR R.F. PASSENGERS

A - ALL SEVERITIES (AIS \geq 1)

IMPACT SITES	INJURIES TYPOLOGY				TOTAL
	SOFT TISSUE	SOFT TISSUE + BONE	SOFT TISSUE + BRAIN	SOFT TISSUE + BONE + BRAIN	
CRANIAL	21	—	13	1	35
FACIAL	7	2	5	4	18
CRANIO-FACIAL	4	2	2	—	8
	32	4	20	5	61

B - MODERATE AND SEVERE INJURIES (AIS \geq 2)

IMPACT SITES	INJURIES TYPOLOGY						TOTAL
	SOFT TISSUE	BONE	BRAIN	BONE + BRAIN	SOFT TISSUE + BRAIN	SOFT TISSUE + BONE + BRAIN	
CRANIAL	—	—	13	—	—	1	14
FACIAL	—	2	5 ⁽¹⁾	4	—	—	11
CRANIO-FACIAL	—	1	2	—	—	—	3
		(cranium+face)					
	—	3	20	4	—	1	28

(x) of which AIS BRAIN \geq 3

NOTA : 2 CASES OF BRAIN INJURY OF AIS 2 WITHOUT HEAD IMPACT.

III - NECK INJURIES

The first thing that needs to be said is that the neck is more rarely and less severely injured than other body regions. As seen in table 5, the neck is ranked as 8th, and in last position, in frequency of AIS ≥ 2 injuries for drivers, and in 7th position for the R.F. passengers. For severe injuries (AIS ≥ 3), the neck is occupying the 7th and next to last position for both drivers and passengers.

III - 1. FREQUENCY AND SEVERITY OF NECK INJURIES

90 % of drivers and 87 % of R.F. passengers did not sustain any lesion to the neck (table 3). When an injury occurs it is in most cases an AIS 1, in 94 % of cases for drivers and 85 % for passengers.

So, the study of injury mechanisms is difficult due to the scarcity of severe lesions and to the imprecision in medical descriptions of minor ones, which are mostly describes as "ache or contusion" without radiological sign.

III - 2. NECK INJURIES MECHANISMS

Neck injuries can be produced by :

- a) A head contact against a vehicle interior component or an exterior object
- b) an overload by unrestrained rear occupant
- c) by restraint system

The influence of overloading by rear seat occupants upon severity of neck injuries is difficult to appreciate. Nevertheless when a rear occupant hits the back of the front seat there is an actual possibility of direct contact head/head or head/neck, even if no lesion is observed to the head (occipital area) of the front seat belted occupant.

III - 3. FREQUENCY AND SEVERITY OF NECK INJURIES ACCORDING TO HEAD CONTACTS (Table 8)

Among the drivers who do not sustain any injury to the head, 9.7 % suffer from a neck injury of AIS ≥ 1 and 0.2 % of AIS ≥ 2 . These frequencies are higher for R.F. passengers respectively 12.3 and 0.8 %.

For cases where a head injury of AIS ≥ 1 is found (including cases described only as "head concussion" without any location sign and for which the possibility of a head contact, if not probable, cannot be quite excluded), the frequency of neck injuries is higher for drivers, just as for passengers.

10.4 % of drivers and 15.9 % of passengers have sustained a neck injury of any severity. In these conditions, frequencies of cervical spine fractures (AIS ≥ 2) are 1.4 % for drivers and 6.3 % for passengers.

TABLE 8 : FREQUENCY OF NECK INJURIES FOR FRONT SEAT OCCUPANTS ACCORDING TO HEAD CONTACT AND OVERLOAD BY REAR SEAT OCCUPANTS.

	AIS HEAD = 0 NO OVERLOAD	AIS NECK						TOTAL	PERCENTAGE OF AIS NECK > 1
		0	1	2	3	4	5		
D R I V E R S	340 89.5	39 10.2	-	-	1 0.3	-	-	380 100	10.5
	41 97.6	1 2.4	-	-	-	-	42 100	2.4	
	170 90.5	17 9.0	1 0.5	-	-	-	188 100	9.6	
	20 83.3	2 8.3	1 4.2	-	1 4.2	-	24 100	16.7	
TOTAL	571 90.1	59 9.3	2 0.3	1 0.2	1 0.2	-	634 100	9.9	
R. F. P A S S E N G E R S	158 89.7	17 9.7	1 0.6	-	-	-	176 100	10.2	
	49 81.6	10 16.7	-	1 1.7	-	-	60 100	18.3	
	35 87.5	3 7.5	1 2.5	1 2.5	-	-	40 100	12.5	
	18 78.3	3 13.0	2 8.7	-	-	-	23 100	21.7	
TOTAL	260 87.0	33 11.0	4 1.3	2 0.7	-	-	299 100	13.0	

III - 4. MECHANISMS OF MODERATE AND SEVERE NECK INJURIES

A - For drivers, there are 4 cases (0.6 % of all drivers) of cervical spine fractures.

In one case of AIS 4 (fracture of vertebral body of C2, C3, C4 with cord contusion) the injury is clearly due to head contact. In another case (fracture of vertebral body of C2 - AIS 3) there is no head contact and injury can be attributed to restraint by belt. For the last two cases of neck injuries (fractures of spinous or transverse process - AIS 2) the medical files contain "head concussion" but the evidence of a head contact is not well established and one of these drivers sustains also an overload by a rear passenger.

B - For R.F. passengers, there are 6 cases of cervical spine fractures (2 % of all passengers).

For 2 of them, there is no head contact nor head injury, and one neck injury (fracture of C7 process - AIS 2) is probably due to restraint by belt, for the other one (displaced fracture of vertebral body of C2 - AIS 3) the overload by rear passenger cannot be excluded.

Four cases are associated with head injuries. One AIS 2 (fracture of C5) and one AIS 3 (fracture dislocation of C6, C7 with transient neurological signs) are consecutive to a head contact.

For the last 2 cases (a fracture of C7 and a fracture of C2 - AIS 2) the only indication of head contact is, again, "head concussion" with no localization, so head contact is possible but not certain, and for one case there is an overload by a rear passenger.

III - 5. NECK INJURIES ACCORDING TO SEX (Table. 9)

It seems that sex of occupants has a great influence on the probability of neck injuries.

The higher frequency of AIS ≥ 1 neck injuries observed for R.F. passengers (13 % against 10 % for drivers) can be linked to the fact that 66 % of them are women for only 19 % among drivers. It is well-known that women neck morphology, being weaker than men's, facilitate occurrence of injuries, in rear impacts for example. In fact, considering the front seat occupants as a whole, one sees that head contact (and lesions) frequency is the same (about 30 %) for men as for women ; but for women the risk of neck injuries is twice, with or without head contact.

Of course other parameters can interfere, some of them may be directly linked to sex as height, but the lack of exhaustive medical information for minor lesions and the small number of severe injuries make further analysis difficult.

TABLE 9. FREQUENCY OF NECK INJURIES FOR FRONT SEAT OCCUPANTS
ACCORDING TO SEX AND HEAD CONTACT

<u>FRONT SEAT OCCUPANTS</u>	<u>FREQUENCY OF AIS NECK = 1</u>	<u>FREQUENCY OF AIS NECK >1</u>
<u>AIS HEAD = 0</u>		
- MALES (N = 424)	7,8 %	0,2 %
- FEMALES (N = 218)	15,6 %	0,9 %
<u>AIS HEAD ≥ 1</u>		
- MALES (N = 182)	6,6 %	1,6 %
- FEMALES (N = 93)	14,0 %	4,3 %

<u>ALL CASES</u>		
- MALES (N = 606)	7,4 %	0,7 %
- FEMALES (N = 311)	15,1 %	1,9 %

CONCLUSIONS

634 drivers and 299 front seat passengers, restrained by retractor seatbelts, who were involved in single frontal impacts have been analysed in order to describe clearly frequency, gravity, kind and origin of head and neck injuries.

The results of this study lead to the following conclusions :

1. Concerning the head

- 67 % of the drivers and 79 % of the front seat passengers were shown to have incurred no head injury,
- among injured people, respectively 43 % of the drivers and 67 % of the front seat passengers did not sustain a head injury,
- brain injuries in the absence of direct head contact are specially few, (less than 1 %),
- more than a half of head injuries are only slight injuries of AIS 1 (drivers : 58 % ; front seat passengers : 52 %),
- injuries resulting from facial impact alone are the most frequent form of injury for the drivers, whereas contact with cranium alone accounts for the majority of cases for the front seat passengers,
- among 100 facial injuries to the drivers, injuries of the soft tissues alone occurred in 74 % of cases, injuries of the soft tissues with bone fracture(s) of the face in 26 % of cases,
- 14 % of the drivers and 10 % of the front seat passengers incurred head injuries of $AIS \geq 2$. The frequency of head injuries of severity $AIS \geq 3$ is 2.3 %, both drivers and front seat passengers,
- among the drivers, half of brain injuries are associated with facial impact alone. This proportion is only 33 % for front seat passengers,
- most of the 119 front occupants who sustained head injuries of $AIS \geq 2$ present brain injuries (79 % of cases), followed by facial bone fractures of $AIS \geq 2$ (32 %). Losses of consciousness > 15 minutes (7.6 %) and skull fractures (2.5 %) are rare,
- under 56 kph of delta V, the proportion (%) of cases of severe head injuries ($AIS \geq 3$) is 0.6 % for the drivers and 0.9 % for the front seat passengers, against respectively 19.5 % and 13 % in more severe collisions,
- the steering wheel for the driver and the facia for the front seat passenger are, in two thirds of cases, the cause of $AIS \geq 3$ head injuries,
- serious head injuries ($AIS \geq 3$), by comparison with other body zone, are ranked 2nd for the drivers and 3rd for the front seat passengers.

2. Concerning the neck

- nearly 90 % of front occupants don't incur neck injuries,
- nearly 90 % of neck injuries are only slight injuries of AIS 1. The frequency of these injuries is about the same with or without head contact, but the risk is twice among women by comparison with men,
- 7 out of 10 cases of cervical fractures are associated with head injury after a direct head impact. The overloading by unbelted rear seat passenger could contribute to cause cervical fractures in 3 of the 10 cases (probably by head to head contact).

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