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### **The Effect of Air Bag Inflation on the Cinematic and the Lesions of a Motorcyclist**

Michelle Ramet, Robert Bouquet, Mounir Bouallegue, François Bermond, Dominique Cesari  
INRETS, Institut National de Recherches sur les Transports et leur Sécurité  
France  
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#### **ABSTRACT**

Despite the development of efficient individual protective means such as crash helmets and padded outfits, motorcyclists represent a high risk group. This is why it was proposed to complete this protection with devices integral with the motorbike: leg protectors and the air bag.

The aim of the motorbike air-bag is to form a screen between the driver and the obstacle which he is likely to crash into when thrown off his machine. However, it is advisable to check the effect of the inflation when the driver's head is close to it: this can be the case of a racing driver or if the driver is bent forwards at the start of the impact.

This is the purpose of this study in which 4 tests were carried out using corpses. These were instrumented to evaluate the violence of the shock received and high speed camera cover made it possible to determine the cinematic. Finally medical imaging and autopsy enabled an exhaustive evaluation of the lesion to be made and determine the seriousness of the lesions received.

Checks were carried out using human corpses, to determine if the sudden application of an inflatable bag in front of a motorbike during an impact is likely to cause accelerations and/or injuries to the head or backbone.

This is done by using cinematographic methods of acceleration measurements and medical examinations likely to answer this question.

#### **AIMS OF THE STUDY**

##### **THE PURPOSE OF THIS STUDY:**

In accordance with a contract, the intention is to verify the safety advantages that would be provided for the motorcyclist by an airbag inflating on the front of a motorbike. The aim of the airbag is to form a screen between the driver and the obstacle which he is likely to hit in a frontal impact situation. It is therefore necessary to experimentally verify the cinematic given to the driver's head during the airbag's inflation, and its repercussions in terms of lesions.

Accidentology shows that most motor driven two wheel crashes are frontal ones (58%) and are with four wheeled vehicles or against fixed obstacles. As with other user categories, speed is an accentrating factor, but numerous studies have shown that impact speed lie between 30 and 45 km/h. The lower limbs are the most frequently involved, followed by head lesions and then the upper limbs. The most serious lesions are head related ones which are often the most frequent cause of death.

The first motorbike airbag tests were carried out in 1973, and some studies were published. Their purpose was to modify the motor-cyclist's forward trajectory during a frontal shock in order to avoid the cephalic end striking the structure of the obstacle, which is usually a light vehicle.

It was normal to think that inflating the airbag would limit shocks to the head, but it was found that it also modified the cinematic of the lower limbs, thus reducing the most frequent and serious lesions in this type of shock.

The originality of the tests reported here is in the use of unembalmed human corpses, and in the investigation means employed, such as the scanner. This was only realisable through the collaboration of the hospital and university departments of Lyon-Grange Blanche.

## METHODOLOGY

The experimental conditions were fixed after discussions with the contracting party: Four tests were requested using unembalmed human corpses:

The experimental protocol defines the body's position as seated in the "fast driving position" on a Yamaha 500 motorbike in such a way that the integral helmet visor is in the axis of the pyrotechnic diffusers, the arms hung over the handlebars, supported under the armpits, with the soles of the feet resting on the foot rests (photo 1).

Acceleration measurements are taken at head level (using a helmet made integral with the head by filling the free space with polyurethane foam).

- Two bi-axial accelerometers (in X and Y) were fixed onto the helmet. They were positioned in the saggital plane at a 90° angle, by means of a metal support.

- A tri-axial accelerometer was fixed on D1 and another one in the mouth, close to the helmets centre of gravity, sealed into the polyurethane foam.

A helmet was placed on the head and made integral with it by means of a polyurethane foam film: 2 bi-axial transducers (in X and Y) were fixed onto the helmet at a 90° angle in the saggital plane, using a metallic mounting.

- Spherical sights placed on the top and back of the head using the helmet, and on D3 made it possible to exploit the cephalic end cinematic.

- The cinematic system comprises 3 cameras 2 being in the lateral position (one for wide angle shots and the other for narrow shots) and the other for filming the subject from above. The cameras film at 1000 frames/sec .

## TESTS

After carrying out a preliminary test on a dummy, 4 tests were made with human corpses:  
The air bag inflation was triggered just after the start up of the cameras and measuring systems. The air bag was inflated by means of two pyrotechnic diffusers triggered simultaneously yielding about 155 litres in a few milliseconds.

After the test, the body was scanned from the skull base up to D3, D4 according to 5mm section planes, firstly following the neuro-ocular plane and then in the axis of the bulk posterior articulations. This was followed by a limited autopsy of the head - neck - first cervical. (See correlations between these two investigation methods).

## RESULTS

All the tests showed that the presence of an airbag inflating in front of the driver considerably changes the trajectories a driver would follow as a result of a frontal shock. It is in fact acknowledged that during a frontal collision, the motorcycle driver will be projected forwards, lifted out of his seat and then hit the obstacle and/or ground at a speed close to that of the motorbike during the shock, since there is no fixed element in front of a In the four tests carried out, the bodies did not experience a natural forward motion, but motorbike which could limit the driver's ejection.

In the four tests carried out, the bodies did not experience a natural forward motion, but were subjected to a violent push backwards, due to the air bag inflation: a "reception" system was provided either side and to the rear of the motorbike (photo 2) to avoid any additional injuries occurring.

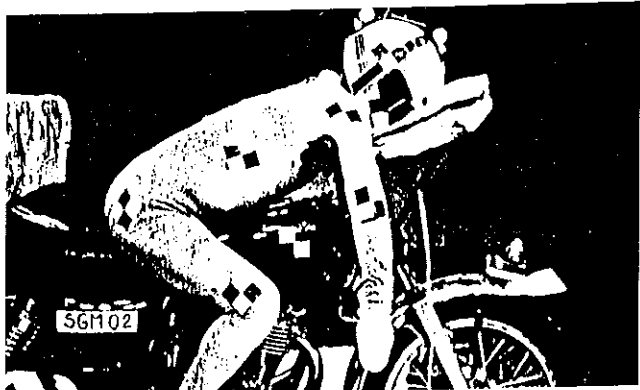


Photo 1: Initial position



Photo 2 : final position

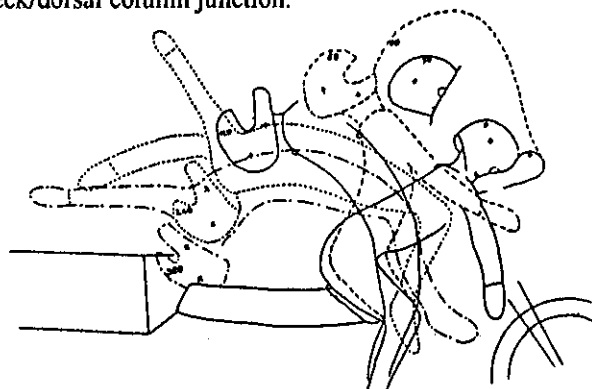
## Description of Tests

Table 1 gives the characteristics of the 4 tests carried out on CAD.

Test N°	age sex weight height	scanner results AIS	autopsy results AIS	HIC
SGM 01	49 yrs. female 60 kg 160 cm	multiple skull base fractures: AIS 4	multiple skull base fractures, dura mater lesion: AIS C7/D1 laxity: AIS 5	8593
SGM 02	47 yrs. male 75 kg 170 cm	total C7 - D1 dislocation: AIS 5	a real C7/D1 dislocation: AIS 5 evulsion of the C7, C8 & D1 roots. Brachial plexus with section left artery: AIS 2	no measurements
SGM 03	36 yrs female 71 kg 169 cm	no obvious bony structure lesions	bilateral evulsion of the extra dural venous plexus at C6, C7, D1 and D2 height: AIS 5?	2742*
SGM 04	66 yrs male 59 kg 176 cm	fracture- compression of C7 with crushing of C7/D1, intra- rachidian bony fragment: AIS 3	fractures of the articulatory masses of C7. Crushing of C7/D1 disc: AIS, bilateral rupture of the yellow ligaments with important peridural haematoma.	HIC* not calculated (no x)

## Trajectories

They were very similar for tests 1, 2, and 4 although the initial position of subject 4 was slightly modified: 60 milliseconds after airbag inflation starts, the bodies become upright, the seat detaches from the seat frame, the neck stretches but the head stays in a physiologically acceptable axis. After 120 milliseconds, the head cinematic is seriously perturbed and the angling with the cervical column exceeds the permissible angles both at the junction of the skull base with the first cervical, and at the neck/dorsal column junction.



General Trajectory of test SGM 01.

Later into the shock, the body tends to position itself in a virtually horizontal position and the head-neck liaison seems freer (less restricted) and thus less

dangerous in terms of lesion risks. Then the body topples over onto the protective mattress placed behind it.

During test N° 4, it had been suggested to change the initial position by lifting up the head into a driving position closer to reality and which would avoid any immediate contact with the released gas. The head was therefore placed in the same axis in relation to the diffusers but 30 cm higher up.

## Head cinematic

We have seen that the sudden inflation of an airbag by 155 litres of gas in the direction of the face of an anatomical subject caused a very significant movement of the upper body with the body being raised up and projected backwards. It is the cephalic segment however which due to the helmet is subjected to the full impact force. It is the cinematic of this segment which accounts for the impact's severity: the hyperextension of the head exceeds the physiological limits in all cases.

This movement is particularly clear for tests SGM 01 and 03. In case N° 3 however, the movement is modified by the bag explosion which occurs at 30 milliseconds: the tear is large enough to stop the bag inflation which mainly

expands in front of the motorbike's fork. After rapidly noting the severity of the movement transmitted to the head, we carried out a 4th test, after modifying the initial position.

The head and trunk were adjusted to about 30°, avoiding the immediate proximity of the pyrotechnic diffusers. However no obvious cinematic differences were noted, and as will be seen below, nor in the lesion type.

The camera filming from above made it possible to see that the head was subjected to lateral flexion movements, which did not seem to have an influence on the lateralization of the injuries since the evulsion of the left

appeared with a slight lateral flexing movement... to the left, which contradicts with the biomechanic generation theories of these injuries.

#### Acceleration measurements

Table N°2 recalls the measurements taken during the tests, but only for three of them, as no measuring path functional during test N° SGM 02.

During the SGM 04 test, the X mouth path was out of order thus no HIC calculations could be done.

*Table 2: Measurements taken during tests*

	SGM01		SGM03		SGM04	
	mini	maxi	mini	maxi	mini	maxi
X	-476,7	446,1	-482,4	274,7	*	*
Y	-55,1	461,4	-50,3	29,8	-61,3	32,4
Z	-202,6	243,3	-54,6	75,5	-105,2	66,2
R		561,8		484,2	*	*
HIC		8593,2		2742,3	*	*

#### Mouth measurements

	SGM01(peak at 2ms)		SGM03(peak at 17ms)		SGM04(peak at 60ms)	
X	-475,0	323,8	-438,0	462,4	-519,5	587,6
Y	-360,0	363,6	-160,0	197,6	-123,4	141,1
R		510,7		476,6		596,2

#### Helmet top

	SGM01		SGM03		SGM04	
X	-413,3	395,6	-278,1	185,0	-138,0	129,9
Y	-76,6	263,8	-187,7	168,4	-38,4	197,9
R		473,6		292,6		219,7

#### Helmet rear

	SGM 01		SGM03		SGM04	
X	-80,5	100,0	-17,8	6,1	-46,8	9,2
Y	-50,4	77,3	-5,7	6,0	-11,4	14,8
Z	-93,4	79,7	-69,3	27,2	-36,4	62,9
R		137,0		71,8		64,1

#### D1 Column Acceleration

\* No measurement

The HIC could only be calculated on two tests, from measurements taken in the mouth, close to the head's centre of gravity using a mounting which positioned the transducer against the palatal roof. The values obtained were very high, this was not surprising in view of the films and trajectories. If we compare the resultants at D1 to the tests carried out with the aim of contributing to the mathematical\* modelling and stay within the tolerance limits (juxta lesion), they are equally very high; the average of the "air bag" results is roughly three times higher than those quoted in the literature, which permit us to say that the forces exerted via the air bag were also very high (around 700 daN): this should be correlated with the lesions noted at the vertebral hinge joints at the head-neck junction.

#### Lesions observed, collations between scanner and autopsy

The lesions observed both by scanner or autopsy were severe. The AIS were between 3 and 5, and did not fully take into account the functional repercussions: It is difficult to pre-judge the repercussions of a venous plexus evulsion at the medulla since the means to evaluate the functional damages is no longer present on the CAD. Nevertheless medically speaking it can be considered that three of the four motorcyclists would have immediately received mortal lesions and the prognosis for subject SGM03 was very unfavourable.

It can be seen that the lesions observed on the scanner are generally underestimated compared to those described by the autopsy examination, except for subject SGM 04 where only the scanner was able to detect the presence of a small intra-rachidian bony fragment which was not found in the autopsy, but which constitutes an unfavourable prognosis factor.

By integrating the histological examinations it would have been possible to determine the status of the spinal cord subjacent to the bone lesions, which would have made it possible to better understand the repercussion of the neck's hyper extension, especially for test SGM 03.

#### CONCLUSIONS

The results of these trials show that although the presence of an air bag stops the driver being projected from a motorbike which crashes head on into an obstacle and thus a priori avoids a random ejection, the thrust of a 155 litre airbag seriously disturbs the head cinematic and induces serious head-neck segment lesions.

Despite these disturbing results, the fact must be accepted that this dispositive did not function as well as it could have done:

1.- The initial position chosen was penalising: the head was placed directly in line with the pyrotechnic diffusers and was therefore subjected to a sharp blast of freed gas.

To resolve this effect the head's position was modified for the last test SGM 04 by raising it by about 30cm.

This modification from the initial position however did not significantly change the cinematic and the lesions were severe.

2. The experimental procedure did not take into account the reality of the inherent movement of a motorcyclist, projected forwards at a speed close to the impact speed, then sharply striking the inflating bag and limiting its inflation, or rather opposing the force of the expanding gas, the force exerted by the trunk and head of the motorcyclist in moving forward, thus in the reverse direction of the forces exerted by the bag on the subject.

Previous tests carried out also indicate a trajectory which is certainly modified by the air bag's presence, which does not stop the forward projection, but reduces the acceleration levels as well as the possibility of antagonistic head/vehicle contact.

3. One could also imagine modifying the design of the air bags by incorporating "Flanges" which would induce an inflation directed frontwards to optimise the head/air bag contact by reducing the sharpness of the contact.

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