# Severe Abdominal Injuries for Car Occupants in Frontal Impact

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**Abstract** - In most of developed countries, the progress made in passive safety during the last three decades allowed to drastically reduce the number of killed and severely injured especially for occupants of passenger cars. This reduction is mainly observed for frontal impacts for which the AIS3+ injuries has been reduced about 52% for drivers and 38% for front passengers. The stiffening of the cars' structure coupled with the generalization of airbags and the improvement of the seatbelt restraint (load limiter, pretension, etc.) allowed to protect vital body regions such as head, neck and thorax. However, the abdomen did not take advantage with so much success of this progress. The objective of this study is to draw up an inventory on the abdominal injuries of the belted car occupants involved in frontal impact, to present adapted counter-measures and to assess their potential effectiveness. In the first part the stakes corresponding to the abdominal injuries will be defined according to types of impact, seat location, occupants' age and type of injured organs. Then, we shall focus on the abdominal injury risk curves for adults involved in frontal impact and on the comparisons of the average risks according to the seat location. In the second part we will list counter-measures and we shall calculate their effectiveness. The method of case control will be used in order to estimate odds ratio, comparing two samples, given by occupants having or not having the studied safety system. For this study, two type of data sources are used: national road injured accident census and retrospective in-depth accident data collection. Abdominal injuries are mainly observed in frontal impact (52%). Fatal or severe abdominal occupant's injuries are observed at least in 27% of cases, ranking this body region as the most injured just after the thorax (51%). In spite of a twice lower occupation rate in the back seats compared to the front seats, the number of persons sustaining abdominal injuries at the rear place is higher than in the front place. In recent cars, the risk of having a serious or fatal abdominal injury in a frontal impact is 1.6% for the driver, 3.6% for the front passenger and 6.3% for the rear occupants. The most frequently hurt organs are the small intestine (17%), the spleen (16%) and the liver (13%). The most common countermeasures have a good efficiency in the reduction of the abdominal injuries for the adults: the stiffness of the structure of the seats allows decreasing the abdominal injury risk from 54% (driver) to 60% (front occupant), the seatbelt pretensioners decrease also this risk from 90% (driver) to 83% (front passenger).

## NOTATION

*EES* Energy Equivalent Speed
*AIS2+* Injuries with an AIS ≥ 2
*PC* Passenger car

## INTRODUCTION

In most of developed countries, the progress made in passive safety during the last three decades allowed to drastically reduce the number of killed and severely injured especially for occupants of passenger cars. This reduction is mainly observed for frontal impacts for which the AIS3+ injuries has been decreased about 52% for drivers and 38% for front passengers [1]. The stiffening of the cars' structure coupled with the generalization of airbags and the improvement of the seatbelt restraint (load limiter, pretension, etc.) allowed to protect vital body regions such as head, neck and thorax. However, the abdomen did not take advantage with so much success of this progress.
The aim of this paper is to highlight that abdominal injuries frequently occur in frontal crash today, either in front seat but especially in rear seats. Studies regarding abdominal injuries in the U.S. are already available in the literature [2, 3, 4].
The first part is based to a descriptive analysis on abdominal injuries from the databases available at LAB while the second part will be dedicated to the adapted counter-measure and their effect on the risk reduction.

## METHODOLOGIE

We are going first to define the stakes of the abdominal injuries according to the types of collision, seat location (front driver, front passenger, and rear passengers), age of occupants and other organs hurt. We shall focus then on the risk curves of the adults involved in frontal impact and we will make a comparison of the average risks following the seat location in the passenger car.
Secondly we shall give a list of counter-measures and we shall estimate their effectiveness.
The assessment method are based on relative risk. For each safety system we compare two accident samples, involved passenger cars with and without the system. The main issue is to obtain two comparable samples (except for the studied system) to avoid biases but keeping in mind to have a correct number of populations in order to have statistically significant results.
For the creation of the injury risk, 2 important notions are used on this paper. First is related to the gravity indicator and the second parameter referring to the violence of the collision.
The injury scale used in this study is the classification according to the Abbreviated Injury Scale 1990 update 98 [1]; AIS is standard codification widespread used in accident research allowing to classify all individual injuries of a victim by body region according to its relative severity on a 6 point scale (1 minor to 6 maximum).
For the relevant marker of the gravity, we selected the variable representing the energy dissipated by vehicles during the crash, the Equivalent Energy Speed (EES). This parameter corresponds to the speed to which it would be necessary to throw a vehicle against a fixed and stiff obstacle to observe the same deformations as those of the accident. Despite the fact that this parameter is an estimation obtained by comparing the deformation shapes of the case with those giving for "similar" crash tests, this estimate is (for our own database) more relevant than other ones such as DeltaV for example.

## DATA SOURCE

For this study 3 databases are used depending on the level of details needed. The general stakes are mainly based on the French injured accident census (BAAC). This database provided by the French road safety observatory (ONISR) contents the exhaustiveness of the injured accident collected by the police during the year. The main weakness of this census is the missing of codification of data on injuries.
To get round that difficulty, we also used GIDAS data (years 2004, 2005, 2008 and 2009).
Regarding the heart on this study, we will use our in-house in-depth database oriented to passive safety (LAB-EDAS), i.e. only injury mechanism and passive safety systems are studied. All accidents are investigated retrospectively. This database contents 16,000 investigated passenger cars, 29,000 occupants and 76,000 known and coded injuries collected by the CEESAR and LAB teams. It is updated every year with approximatively 300 new vehicles. These injured accidents are based on 2 accidents selection criteria: systematic and targeted methods.
For the systematic method, all passenger cars having at least one injured occupant and involved on accident inside a defined region (North-West of Yvelines department) are collected. Investigations are realized by specialists with an identification of the vehicles 1 or 2 days after the accident. In this case, all the vehicles involved are analysed (any brands, any violence, and every types of collision). The studies require a narrow and reliable contact with Police, hospitals and wreckage area. Every investigated accident gives rise to the constitution of a very complete file (vehicle form, occupant form, infrastructure form, injury form, deformation form, reconstruction form, pictures …). In this paper this database will be named LAB-Zone.
For the targeted method, injured accidents are selected from a priority list (new vehicles, accidents with children, specific type collision …). The cases are investigated two months after the accident following the same process as detailed before. The accidents are selected from the monthly files of the traffic accidents supplied by the Police.
The LAB-EDAS database gathers the LAB-Zone database and the targeted accident cases.

## RESULTS

We're focusing our analysis on belted passenger cars only.

### Descriptive analysis

Here, the frequencies of the abdominal injuries are presented respectively from the LAB-Zone and GIDAS Databases in order to have comparisons.

#### *AIS2+ Abdominal injuries frequencies according to the type of impact*

If we focus on belted passenger car occupant having a level of abdominal injuries higher or equal to 2 (noted AIS2+) we can see that frontal impact is the main typology represented in the both samples.

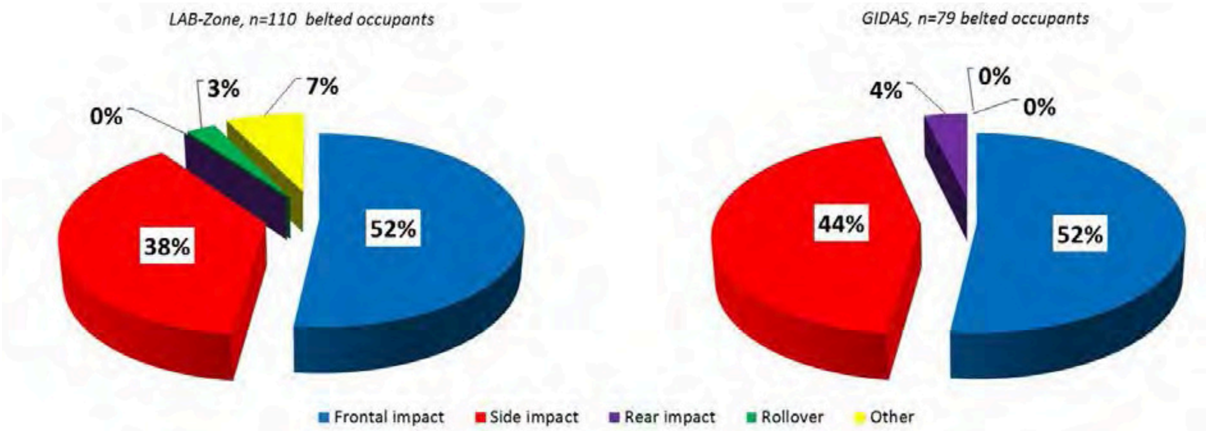


Figure 1. Distribution of belted occupants having AIS2+ abdominal injuries regarding the type of impact

We can note that both sample are small. One of the reasons is that the mean of the EES distribution for the selected sample (belted occupants involved in frontal impact) in the available databases are low too (*Table 1*). The observation of abdominal injuries requires higher collision speeds in order to have stronger frontal occupant deceleration and to cause constraints of the belt on the belly (cf. risk curves below).

| | | | EES (km/h) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | n | Min | 1st Qua. | Median | Mean | 3rd Qua. | Max. |
| GIDAS | All | 3760 | 1 | 7 | 16 | 18 | 25 | 120 |
| | AIS2+ Abdo | 41 | 10 | 26 | 44 | 44 | 58 | 87 |
| LAB-Zone | All | 2101 | 5 | 28 | 35 | 38 | 45 | 110 |
| | AIS2+ Abdo | 57 | 27 | 48 | 55 | 56 | 65 | 80 |
| LAB-EDAS | All | 3528 | 5 | 38 | 50 | 51 | 63 | 110 |
| | AIS2+ Abdo | 297 | 25 | 55 | 65 | 64 | 73 | 110 |

*Table 1 : Statistical summary of the EES distribution vs database for belted occupants involved in frontal impact*

Thus we observed that the majority of the abdominal injuries (serious to fatal) are present in frontal impact and it is exclusively on this type of impact that continues the study.

#### *Abdominal injuries distribution according to the seat location in frontal impact*

The Figure 2 shows the distribution of the belted occupants involved in frontal impact with AIS2+ abdominal injuries according to the seat location in the passenger car. For GIDAS, 66 % of the population are drivers, 24 % are front passengers and 10 % are seated on the back. The sample size is reduced, only 41 occupants. One of the explanations is that the EES distribution of the complete GIDAS sample is very low (mean = 18km/h) and in this range of violence it becomes difficult to find abdominal injuries.

For the LAB Zone database, the problem is quite identical. Only 57 occupants are involved in this typology. Nevertheless the EES mean for the overall sample is higher than GIDAS (20km/h more) and we begin to see a gap of the distribution of the occupants towards the back seats.

For the LAB-EDAS database, the size of the sample is more important (around 300 occupants). This gap is due to the criteria to select accident cases because we mainly focus our selection on serious injured accidents. For the overall population on recent cases (from year 2000), we can observed that the mean of the EES is clearly higher than the other ones (51 km/h). Due to the increase of the deceleration level sustained by these occupants (higher collision speeds and the increase of the stiffness of the structure of recent cars) the distribution of injured occupants changes and becomes more marked towards the back seats.

This observation leads to predict that in frontal impact, the more the EES increases, the more the risks to be injured at abdomen at the back seat increases compared to the driver. This is also the case for the front passenger with a lower effect. This will be verified in the next section. There is no bias regarding the occupation rate in these 3 databases. In each sample, for 10 occupants, 6 - 7 are drivers, 2 are front passenger and 1 is seated at the back.

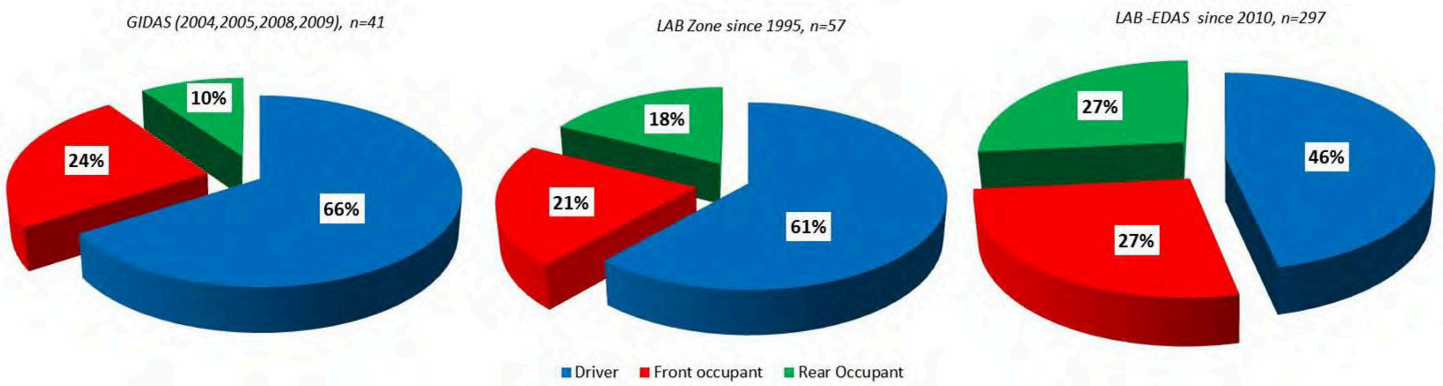


Figure 2. Distribution of belted occupants involved in frontal impact and having AIS2+ abdominal injuries regarding the seat location

### *Distribution of other AIS3+ injuries by body region (all seats)*

We now focus our analysis on the LAB-EDAS database and we select passenger car designed from 2000 and only MAIS3+ injuries for belted occupants involved in frontal impact. The sample is mainly composed by French car (40% Renault and 40% PSA) and on 20% by other brands. The body region the most frequently affected at this level of gravity (Figure 3a) is the thorax (51 %), followed by the abdomen (27 %) and the lower extremities (23 %).

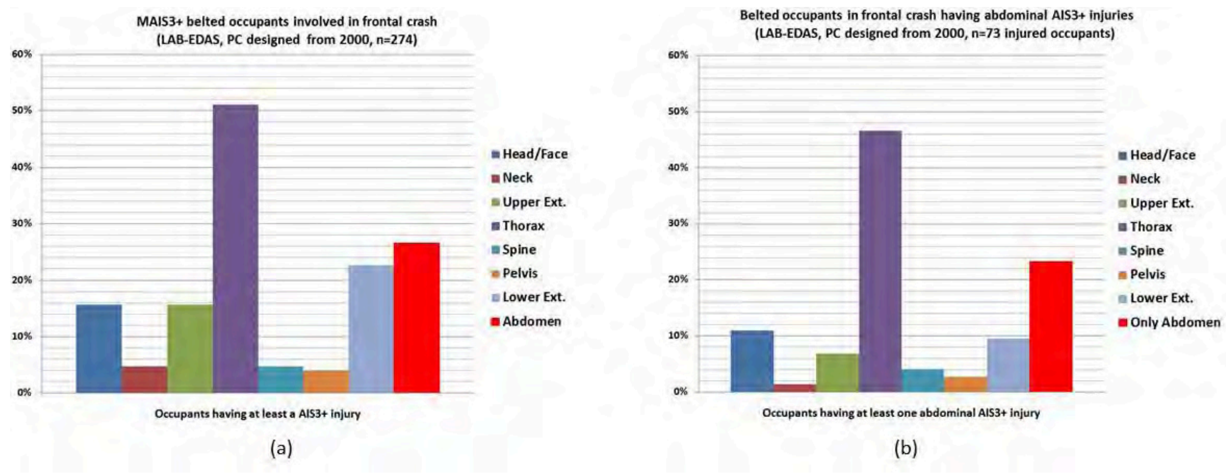


Figure 3. Distribution of injuries by body region for belted occupant involved in frontal crash

For the Figure 3b only occupants having abdominal AIS3+ injuries has been selected and we plotted the distribution of the others injuries regarding the body region affected.
In 23 % of the cases, occupants have only abdominal injuries without any AIS3+ injuries located in other body region. It is interesting to notice that in approximatively half of the cases, occupants also have AIS3+ thoracic injuries, other body regions having frequencies lower or equal to 10%.
This important frequency of thoracic injuries has to be kept in mind for the following paragraph where we will see the distribution of the abdominal injured organs.

### *The most wounded organs in the abdominal region*

Regarding the abdominal region, 23 organs can be coded with the AIS 98 [1].
In the following table, we select belted occupants involved in frontal impact having either AIS3+ or AIS2+ abdominal injuries (LAB-EDAS). We can observe that for these 2 samples, only 8 organs on the 23 available represent 90% of the population. Among them, the top 3 is composed by the liver, the spleen and the small intestine and count for 45 % of the overall injuries.

| AIS2+ | | | Abdominal Organs | AIS3+ | | |
|---|---|---|---|---|---|---|
| n | % | rank | | rank | n | % |
| 141 | **16%** | 1 | **Liver** | 3 | 83 | **13%** |
| 140 | **16%** | 2 | **Spleen** | 2 | 98 | **16%** |
| 112 | **13%** | 3 | **Jejunum, Ileum (small intestine)** | 1 | 102 | **17%** |
| 99 | **11%** | 4 | **Soft tissues** | 7 | 42 | **6,8%** |
| 77 | **8,9%** | 5 | **Peritoneum** | 4 | 64 | **10,4%** |
| 75 | **8,7%** | 6 | **Mesentery** | 5 | 62 | **10,1%** |
| 67 | **7,7%** | 7 | **Colon (large intestine)** | 6 | 56 | **9,1%** |
| 52 | **6,0%** | 8 | **Kidney** | 8 | 26 | **4,2%** |
| 22 | 2,5% | | Retroperitoneum, urinary organs | | 20 | 3,2% |
| 21 | 2,4% | | Pancreas | | 15 | 2,4% |
| 11 | 1,3% | | Large vessels | | 10 | 1,6% |
| 10 | 1,2% | | Duodenum | | 9 | 1,5% |
| 10 | 1,2% | | Urinary bladder | | 9 | 1,5% |
| 8 | 0,9% | | Stomach | | 7 | 1,1% |
| 20 | 2,3% | | Others organs | | 13 | 2,1% |
| ***865*** | ***100%*** | | ***Total*** | | ***616*** | ***100%*** |

Table 2 : Distribution of the frequencies of the injured organs in abdominal region

The fact of finding organs located at the top of the abdomen such as the liver and the spleen can be explained by the constraints of the seatbelt on the thorax or the impacts against the steering wheel (let us not forget that in half of the abdominal injuries cases occupants also have thoracic injuries and that the liver and the spleen are under the lower ribs of the thorax). The lap belt also provokes efforts obliging organs to move in the abdominal cavity and if intestines can be "mobile", the liver and the spleen "are more fixed and be constrained" and thus more exposed to the hurts.

### *Age regarding the seat location*

To study the occupation rate of seat location according to the age of the passengers (occupants involved in frontal impact) we're going to use the BAAC database. On the following text we consider an adult as a person having 10 years old or more. We chose this threshold compared to the French regulations which does not make any more compulsory the use of specific restraint device for child from 10 years old.
In our sample only adults are located at the driver position. The front passenger seat is occupied in 99 % of the cases by adults while they represent 79% of back seats location.
There is no majority of children located at the back seat position. This also comes true when we observe all the occupants whatever the use of the seatbelt or the type of collision.

### *AIS2+ abdominal injury risk curve*

From now, the study concerns only passenger car occupants involved in frontal impact , from 10-years-old (named adults) in cars designed from 2000 (named recent PC).

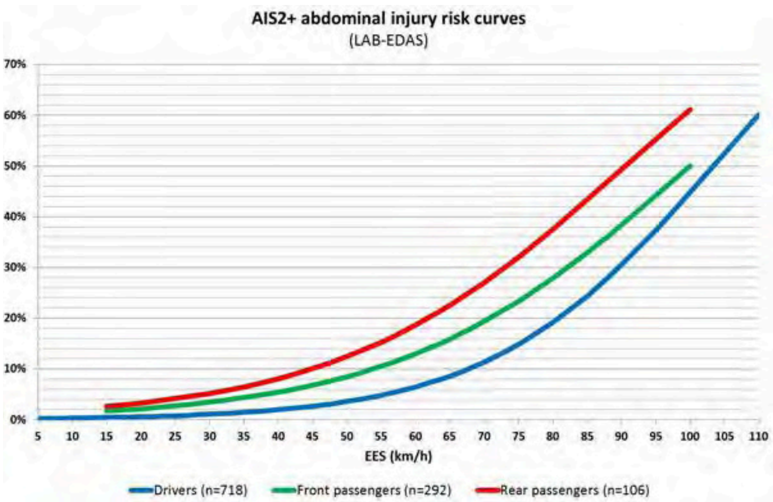


Figure 4. AIS2+ abdominal injury risk curves for adults in recent PC vs seat location

These 3 curves, estimated by logistic regression, represent the risk of having an AIS2+ abdominal injury level according to the seat location (driver, front passenger and rear passenger) and to the EES.

In order to have a sufficient size of the samples (in particular for the back seats occupants) we choose to work with the AIS2+ injury level. Another reason is the fact that the AIS gives an indication on the immediate injury risk while abdominal injuries can be more delicate to deal in the time due to the potential risk of septicaemia or worsening on fragile organs such as the spleen.

From these curves, we can notice that below a speed of 30-35 km/h the injury risk is very low. The proportion of 30 % of injury risk is reached only from very high value of EES (beyond 70 km/h).
On average, the AIS2+ abdominal injury risk for the rear passengers is 40 % higher than the risk for the front passengers and 3 times upper than the driver one. Regarding the front passenger, its risk is 2 times more important than the driver one.
Age and sex effects has been analysed for these 3 curves. These two variables were added as explanatory variables in the logistic regressions: they are never statistically significant. In our sample,

neither the age, nor the sex, have an effect on the risk of AIS2+ abdominal injury level, whether it is for the driver, the front passengers or the rear occupants.

### *Mean AIS3+ abdominal injury risk*

The mean injury risk is defined as the probability to have a related injury when the occupant is involved in a described collision (frontal impact) and for any violence of the crash (EES). Here, the mean risk means that the injury risk has been estimated for a mean EES.
In the Figure 5 we estimated AIS3+ abdominal injury risk for the occupants involved in frontal impact according to its seat location. All the EES values are here taken into account.

The average AIS3+ abdominal injury risk differs in important way according to the seat location. The front passenger has 2.3 times more risk than the driver. The risk on rear seats is clearly more important than for front seats, the rear passenger has 4.1 times more risk than the driver.
For the driver, this lower value compared to other occupants can be explained by the fact that in 2 on 3 accident cases, the driver is affected by a direct intrusion limiting the submarining effect because in these cases the backward movement of dashboard comes to stop the forward movement of the lower extremities. Thus the pelvis cannot move forward anymore and the lap belt does not go back up over the iliac crests avoiding or limiting abdominal injuries. Another reason is that during the last decades the driver also benefited of the evolutions of the passive safety [**2**] more than other occupants (double pretension, anti-slide hump active or not, knee airbag, etc.).

The front passenger is penalized by a placement naturally more distant from the dashboard and by a more "relaxed" position on his seat than the driver which facilitates the submarining effect. Another point is that intrusions are less frequent and less important than for the driver.

The rear occupants are often more "relaxed" on their seat too. Seatbelt buckles are sometimes too high due to ergonomic constraints. They are often not equipped with pretension system and load limiter. In case where a load limiter is present (planned to decrease the thoracic pressure) the deceleration due to the crash unwinds the seatbelt what modifies the coupling of the pelvis which tends to turn under the lap belt at the end of a certain travel distance. Another reason concerns the design of the rear seat cushion that is lighter in structure than the front seats and deprived of anti-slide hump. Furthermore, all these occupants undergo a more and more strong deceleration by the increase of the stiffness of the recent cars.

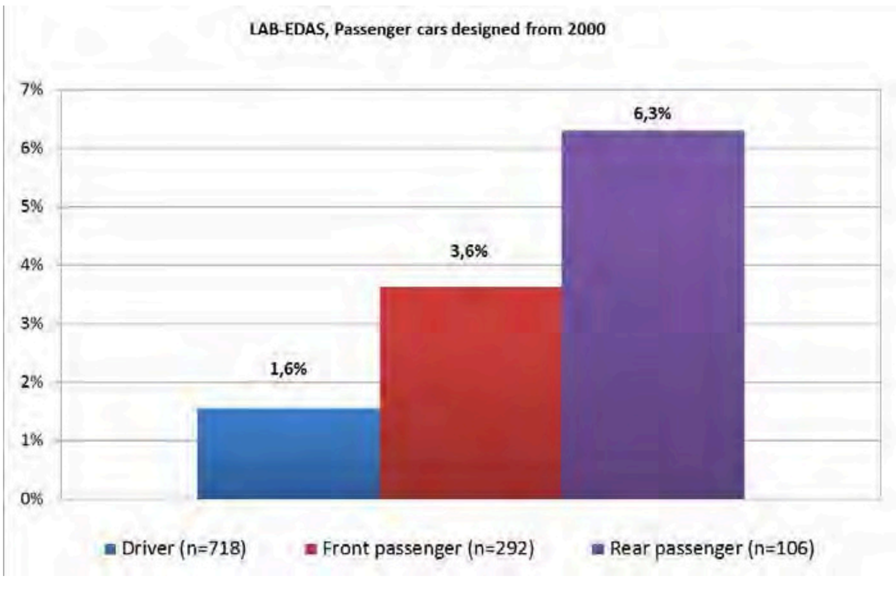


Figure 5. Average AIS3+ abdominal injury risk according to the seat location

## Dedicated counter-measures

The serious abdominal injuries are frequently the consequence of a too important effort applied by the seatbelt to the abdomen. When the lap belt is not anymore on the iliac crests, the lap belt move on soft tissues and other organs of the abdominal region. In this region, there is no organ strong enough to face efforts of the lap belt (the abdomen supports 4 times less effort than the pelvis) and the belt sinks into the abdomen creating serious injuries. This phenomenon is called "submarining" [7,8]

Figure 6. Illustration of the submarining phenomena during a frontal impact

The most known counter-measures to fight against the submarining are the following:

- A good positioning of the seatbelt and the good positioning of the occupant
- Low anchorage points of lap belts.
- A seat-cushion structure which does not collapse under the effort of the occupant.
- An anti-slide hump (active or not) on the seat-cushion
- "Anti-burst" to stop the travel of the rear seat
- Pretensioner system more effective.
- A good restraint of the pelvis (by the pelvis or by the knees)

For some of these safety systems, we are going to assess their effectiveness in avoidance of the abdominal injuries in frontal impacts.

### *Effect of a good behaviour of the seat*

During a frontal impact, the belted occupant exercises a vertical pushing force downward by this/her pelvis on seat-cushion. This effort is particularly more important if the impact declaration is high and the intrusion is low.

Figure 7. Real case: frontal impact at 65km/h against a tree, with a driver having an AIS4 injuries at abdominal region (dilacerations of abdominal muscles and rupture of the colon).
The seat-cushion of the driver is collapsed on 20cm.

To estimate the effectiveness of a stronger structure of the seat avoiding submarining phenomena, we are going to compare 2 populations, one equipped with a stronger structure of the seat, and the other one equipped with seats that collapse easily. We observe the frequency of AIS3+ abdominal injuries. The LAB-EDAS database is used. To have a minimum of crash deceleration we selected accident cases with EES from 45 km/h.

Population 1: robust seat-cushion structure
Population 2: Collapsed seat-cushion

| Belted front occupants | Number | Mean frequency (abdominal AIS3+ injuries) |
|---|---|---|
| Population 1 : Driver | 254 | 6,6% |
| Population 2 : Driver | 92 | 13,9% |
| Population 1 : Front passenger | 200 | 6,3% |
| Population 2 : Front passenger | 52 | 15,8% |

Table 3 : Comparison of the AIS3+ abdominal injury population regarding the structure of the seat

For the drivers and front passengers, a stronger structure of the seat-cushion which does not undergo vertical deflection offers a very good counter-measure against the submarining.
The reduction of the AIS3+ abdominal injuries is 54% (statistically significant) for the driver and about 60% (statistically significant) for the front passenger.

### *Effect of the seatbelt pretensioner*

Pretensioners system tightens and reduces slack in seat belts to protect occupants from rapidly moving forward in the event of a crash. This system allows a better coupling between the occupant and his/her seat and to reduce its relative speed with regard to the structure of the vehicle in front of him/her.
2 types of pretension can be found on passenger cars: the “simple pretension” (pretensioner located at the buckle or in the belt retractor) or the “double pretension” (2 pretensioners buckle & anchor or belt retractor & anchor).

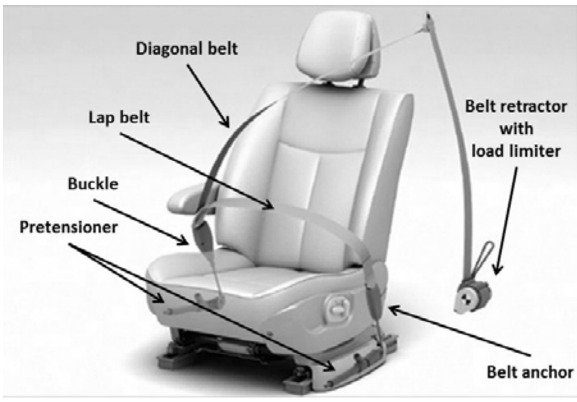


Figure 8. Illustration of seatbelt with double pretension and load limiter

For the estimation of the effectiveness of this system we’re going to study 2 types of device, a unique pretension system and the double pretension system.

For the unique pretension, only passenger cars designed in years 90 will be used. This choice allows to not have too much differences in the stiffness of the vehicle structure; from years 2000, this

stiffness increases appreciably and before 1990 the structures are less stiff. Furthermore from 2000s, there are almost no more cars without pretension.
In that case we compare the 2 following populations:

- Population 1: occupants having a unique pretension system (85% at the buckle, 15% at the seatbelt retractor)
- Population 2: occupants without any pretension system

For the both population, we selected only passengers cars without airbags and with an intrusion of the dashboard limited to 5cm.

| Belted front occupants | Number | Mean frequency (abdominal AIS3+ injuries) |
|---|---|---|
| Population 1 : Driver | 253 | 0% |
| Population 2 : Driver | 204 | 1,7% |
| Population 1 : Front passenger | 180 | 0,8% |
| Population 2 : Front passenger | 115 | 4,8% |

Table 4 : Comparison of the AIS3+ abdominal injury population regarding the unique pretension

None of 253 drivers equipped with simple pretension has AIS3 + abdominal injury while there are 2 drivers on 204 for the population 2 (not equipped with the pretension). Considering the low number of injured occupants these results are not significant.
For the front passenger the reduction of the risk by the simple pretension is significant. This system allows to reduce AIS3+ abdominal injuries by 83% (63% for the AIS2+).

Regarding the double pretension system, we selected passenger cars designed from 2000.
In that case we compare the 2 following populations:

- Population 1: occupants having a double pretension system
- Population 2: occupants having a unique pretension system

For the both population, we selected only passengers cars without knee airbags and with an intrusion of the dashboard limited to 5cm.

| Belted front occupants | Number | Mean frequency (abdominal AIS3+ injuries) |
|---|---|---|
| Population 1 : Driver | 193 | 1,1% |
| Population 2 : Driver | 266 | 1,9% |
| Population 1 : Front passenger | 63 | 0,5% |
| Population 2 : Front passenger | 198 | 4,5% |

Table 5 : Comparison of the AIS3+ abdominal injury population regarding the double pretension

From this table we can see that drivers equipped with double pretension have an average AIS3+ abdominal injury risk 42 % lower compared with the driver equipped with simple pretension, but this result is not statistically significant and request to be verified when a more consequent sample will be available.
Concerning the front passengers, this risk for those who are equipped with a double pretension is 90% lower than those equipped with a simple pretension, this result being statistically significant.

### *Effect of the knee airbag*

Knee airbags are installed in the lower portion of the dashboard, directly in front of the driver's knees. When a collision occurs, they inflate to fill the space between the dashboard and the driver's lower legs. By reducing the amount of movement of the occupant's pelvis region and back, these airbags reduce the load on the pelvis support area.
In order to estimate the effectiveness of this device, we compare the two following populations:

- Population 1: drivers equipped with knee airbag (without double pretention)
- Population 2: drivers not equipped and without double pretension

For the both population, we selected only passengers cars designed from 2000 and with an intrusion of the dashboard limited to 5cm.

| Belted drivers | Number | Mean frequency (abdominal AIS3+ injuries) |
|---|---|---|
| Population 1 : with knee airbag | 50 | 0% |
| Population 2 : not equipped | 279 | 2,3% |

Table 6 : Comparison of the AIS3+ abdominal injury population regarding the presence or not of the knee airbag

No AIS3+ abdominal injury is observed for the sample equipped with airbag of knee (only an AIS2 in the spleen is listed) while 9 cases are present in the population 2. Because the size of the populations are not big enough the estimation of the effectiveness is not possible here.

*Effect of double pretension coupled with knee airbag*

Considering the previous analysis, the combination of the double pretension and the knee airbag, in theory, present a big effectiveness in the reduction of abdominal injuries.
However, the LAB-EDAS database, includes only 12 passengers cars involved in frontal impact and equipped with both systems. Any statistical processing is consequently excluded.
Nevertheless, it is interesting to indicate that among this 12 passenger cars (11 Citroën C4 Picasso and 1 Mercedes C Class), no abdominal injury is observed on the belted drivers. The EES of these crashes are relatively high and go from 28km/h to 105km/h with a mean and a median at 60 km/h.

## CONCLUSION

The abdominal injuries are mainly observed in frontal impact (52%). For this type of collision the abdomen is the region the most severely injured (AIS3+) just after the thorax.
In the abdominal region, the liver, the spleen and the small intestine are the most often injured organs.
The deceleration level plays an important role on abdominal injuries: the more the violence of impact increases, the more abdominal injuries are observed for front passengers and especially for the rear occupants.
For the adults: the rear passenger has 4 times more risk to have severe abdominal injuries than the driver and 1.7 times more than the front passenger. The risk of severe abdominal injuries is a major problem for the rear passengers and for the front passenger but not for the driver (do not to forget the thorax which is always at the top of the severe injuries risks).

Regarding adapted counter-measures:

- the resistance of the seat-cushion don't have to be neglected
- the location of the seatbelt buckles have to be low
- Prevent the displacement of the pelvis by pretension, anti-sliding hump (active or not) or airbag knee without focusing to avoid small intrusions

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