UNEXPECTED DEATHS IN AIRBAG EQUIPPED CARS: CASE REPORTS

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ABSTRACT

Airbags promised to usher in a new generation of restraint systems; nevertheless, some Authors described lesions associated to the use of air bags themselves.

Such airbag lesions are described in the literature as facial bruising, corneal abrasions, finger distortions; these findings may be rather disturbing for their aesthetic or functional long-term consequences, but they are surely not life-threatening.

This paper describes three crashes involving airbag-equipped cars, in which the driver or the front passenger sustained fatal lesions without intrusion of the passenger compartment. Two fatal cases regard drivers, with immediate or delayed exitus; one case regards an unrestrained passenger that was found dead at the scene.

Postmortem data were available for two cases and are discussed with concern to the pathogenesis of lesions.

According to the literature and to the dynamic of impacts, there is strong suggestion that the described fatal lesions have been produced by the airbags themselves.

Possible risk factors for out-of-position occupants, as well as issues for smart systems, are discussed.

Standard crash test do not foresee that a vehicle might be decelerating before the impact; our experience suggests that also the testing procedures ought to be modified in order to detect chances of out-of-position movements.

Airbag deployment may be dramatically dangerous if the seat belts are not worn. The last assertion is categoric especially for the right passenger, whose body may more easily be displaced within the air bag inflation area during the braking phase that often precedes the impact.

BACKGROUND

The first automobile airbag patent was filed in 1949 and issued in 1953, but airbag readiness was controversial until the 1970s, with the development of the sodium azide propellant inflator. Later, Federal Motor Vehicle Standard 208 required automatic crash protection for all passenger cars manufactured after 1989.

An estimated 40% of the new car fleet in the United States will have airbags, approaching one hundred per cent within the next few years for full frontal protection. In Europe, airbags are standard equipment at least for the driver on luxury and upper-middle cars. Passenger airbags are more often offered as optional.

Therefore, it has been estimated that by the turn of the century more than half million airbag deployments will occur each year.

Some works in the literature deal with the effectiveness of airbags in preventing or mitigating impact injuries. The overall advantage of this passive restraint system is perhaps beyond reasonable doubt; however, some problems are emerging in particular situations, particularly with out-of-position occupants. A characteristic groups of lesions has been described, comprising skin abrasions and bruisings, finger trauma, corneal abrasions, and more severe thoracic lesions.

This paper summarizes an investigation of some accidents involving airbag-equipped cars with fatal outcome, with particular focus on the correlation between the dynamics of airbag deployment and the pattern of injury.

MATERIALS AND METHOD

With the collaboration of a group of Road Police departments throughout Northern and Central Italy, we identified and investigated crashes of airbag equipped cars

The study started in the Summer 1993 and is ongoing. For case identification, we scanned all reported crashes, looking for car models potentially equipped with airbag, such as Volvo, Mercedes-Benz, BMW, Japanese models, and some '94-model-year European cars, checking case by case if the device was actually present in the vehicle.

For each case, we collected the following data to the extent available:

- Site, date and hour of the crash;
- Crash severity;
- Type, model and version of the vehicle;
- Manufacture date and place of the vehicle;
- Deformation of the subject vehicles, both external and internal;
- Deformation of other colliding vehicles;
- Description of lesions, from clinical records and, in fatal cases, from autopsy examinations when available;
- Any other circumstantial information, including eyewitnesses reports.

We also directly examined each involved vehicle.

Injury severity was assigned according to the Abbreviated Injury Scaling, 1990 Edition.

RESULTS

Because of the rarity of airbags in the Italian car fleet, we found only 16 crashes, most of them with moderate or no injuries (AIS ≤ 2).

With the help of Police officers and newspapers accounts, we have knowledge of around a dozen other cases, sometimes with minor consequences to vehicles and no injuries at all, but we had no access to any substantial information about these crashes.

In our files, 5 out of 16 crashes had fatal consequences to at least one occupant; ejection from the vehicle despite the airbag deployment was observed in one non-fatal case (Jeep Cherokee).

In one case no lesions were suffered by both driver and passenger

Vehicle type	Position	Lesions	AIS score	ISS
Mazda MX-5 Miata	driver	multiple metatarsal fracture	2	13
		Mesenteric laceration with ileum perforation and hemoperitoneum (2000 cc)	3	
Mercedes-Benz 500 SE	driver	abrasions to forearms and thigh	1	26
		sternum fracture	2	
		multiple bilateral rib fractures	4	
		heart contusion with right atrial lesion	5	
Mercedes-Benz 300 CE	driver	bilateral multiple rib fractures	4	26
		intrahepatic hematoma + hemoperitoneum	3	
		diffuse bruisings	1	
Mercedes-Benz 300 CE	pass.	closed thoracic trauma n.f.s.	9	n.a.
		right arm fracture	2	
		facial contusion n.f.s.	1	

Table I: Summary of the main clinical features of the described cases.

(Mercedes-Benz 600 with double airbag), but the two occupants of the collided car (Fiat 127), that was completely destroyed, died. In one fatal casethe car was severely intruded (Ford Mondeo) and will not be discussed here.

Surprisingly, 3 cases in our sample had a fatal outcome although the passenger compartment was practically intact. These cases with unexpected fatal outcome were thoroughly investigated and are discussed in detail in this paper. The injuries of these cases are summarized in Table I.

All of our cases involve cars regularly registered in Italy (with the only exception of the Mercedes-Benz 300 CE that has a Swiss-issued plate) and with Italian drivers and passengers.

Case no. 1

On a secondary road near Garda lake, a Mazda MX-5 Miata (Figure 1A) sustained an offset head-on impact on a bend with a Lancia Thema.

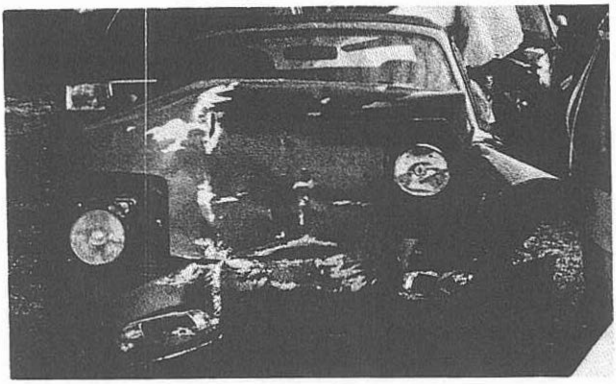
The Mazda Miata, that had been first marketed in the Netherlands, was equipped with a tethered, small-size airbag; its passenger compartment had not been deformed at all (Figure 2). The lower rim of the steering wheel, however, was slightly bent, at around 10°. The Lancia Thema was deformed in the whole frontal line, with moderate intrusion (Figure 1B).

This Japanese car was fitted with a strange type of seat belts, provided with something like a "stress dampener" that will be better described and discussed later (Figure 9).

The unbelted driver of the Lancia Thema, female, aged 51, suffered a large wound at the right knee with ligament transection (AIS 2), multiple rib fractures at the right side (AIS 2), right femur fracture (AIS 3), chin contusion (AIS 1). The Thema was not equipped with airbag and therefore we will not discuss the lesions of its driver.

The driver of the Mazda, male, aged 45, was able to get down from the car and comment to rescuers that "*the airbag had not worked*". He was admitted into

A



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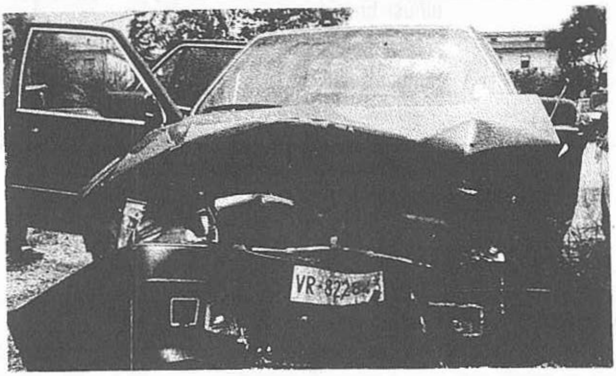


Fig. 1: Frontal view of the Mazda MX-5 Miata (A) and of the Lancia Thema (B).

a local hospital, where he sustained abdominal CT scan and ecography, and rapidly his clinical conditions worsened into shock.

With a diagnosis of haemorrhagic shock due to closed abdominal trauma and closed trauma to left hemithorax, the patient was urgently transferred to the resuscitation dept. of another hospital, suffering a cardiac arrest in the meanwhile (around four hours after the crash).

An explorative laparotomy documented the presence of extensive hemoperitoneum (2000 cc) resulting from a mesenteric root laceration and small ileum perforation (AIS 3). The patient suffered also a right metatarsal multiple fracture (AIS 2).

The patient remained in coma (stage III-IV), sustained a second laparotomy at eight days from the crash, and died 20 days later from the traumatic event without regaining consciousness.

Case no. 2

On an urban road, in the early morning a Mercedes-Benz 500 SE impacted a tree after skidding on grass for around 12 meters (Figure 3). No traces of braking were found.

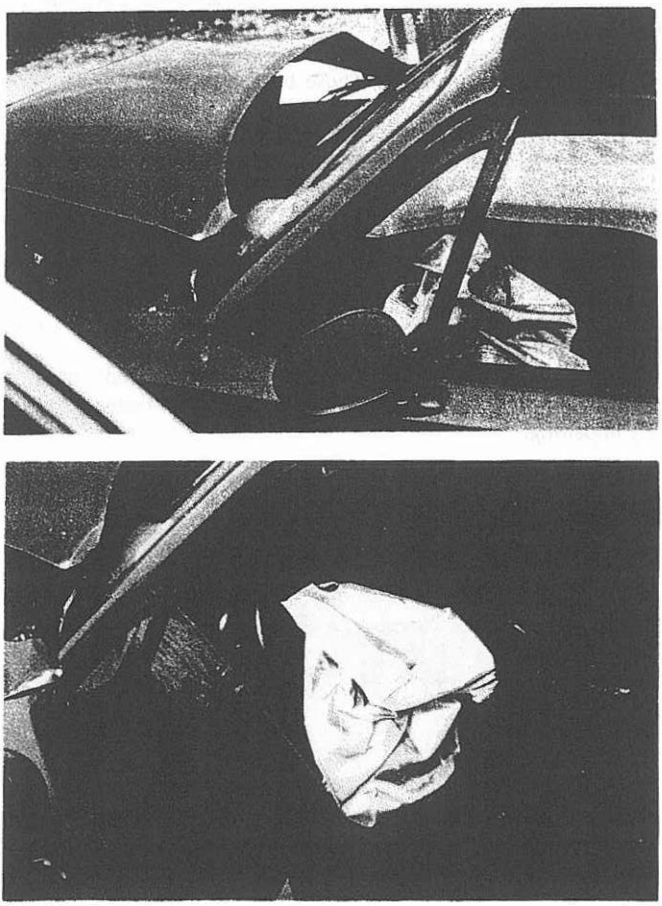
The car had been first marketed in Germany; the airbag deployed appropriately (Figure 5). The front of the car suffered severe intrusion, while the passenger compartment was practically intact (Figure 4 and 5).

The driver, male, aged 37, was transported to the resuscitation dept. and was declared dead one hour later. The external examination and the autopsy documented abrasions to forearms and to right thigh (AIS 1), sternum fracture (AIS 2), multiple bilateral rib fractures (AIS 4), heart contusion with damage to right atrium (AIS 5). The cause of death was recorded as cardiac tamponade.

Case no. 3

On the motorway "Serenissima", early in the morning, a Mercedes-Benz 300 CE was involved in a slightly offset head-on collision against the bottom of an overturned truck (Figure 6). The car had been marketed in Switzerland; it was fitted with ABS and no traces of braking were found.

Both the driver and the full-size passenger airbags deployed regularly; the passenger compartment was slightly intruded from the driver side, but there was no intrusion at the passenger side (Figure 7). The car floor had been bent upwards with the driver's seat, and the steering wheel had been displaced in the same direction.



A

B

Fig. 2: Passenger compartment of the Mazda MX-5 Miata (case no. 1).

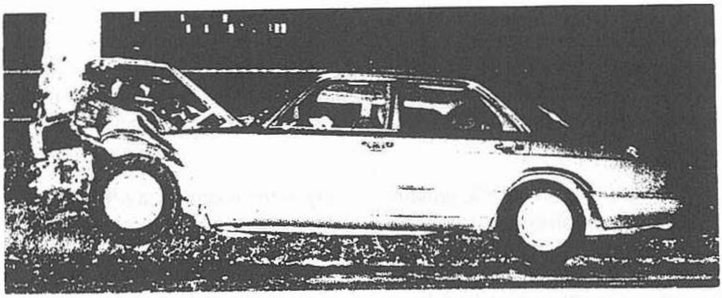


Fig. 3: Crash scene of the Mercedes-Benz 500 SE (case no. 2).

The driver, male, aged 44, suffered bilateral multiple rib fractures (AIS 4), intrahepatic hematoma with hemoperitoneum (AIS 3), diffuse bruisings (AIS 1) and was transferred to the resuscitation dept.

The passenger, male, aged 53, was found dead at the scene (Figure 8). The cause of death was simply classified as violent traumatic agent ("polytrauma"). From photographs, however, it is possible to ascertain a fracture of the right arm and an area of contusion around the nose, but no evidence of bleeding from nose or mouth.

The significance of these pathological findings will be discussed later.

The lesions suffered by the deceased right passenger may be classified as closed thoracic trauma not further specified (AIS 9), right arm fracture (AIS 2), facial contusion not further specified (AIS 1).

DISCUSSION

The probability of a driver to be injured by a deploying airbag has been reported in the literature. With the increase of airbag equipped cars, these case have emerged in the last two years.

Early clinical case studies reported injuries associated with airbags as generally abrasions and small bruisings, neither life-threatening nor permanently impairing.

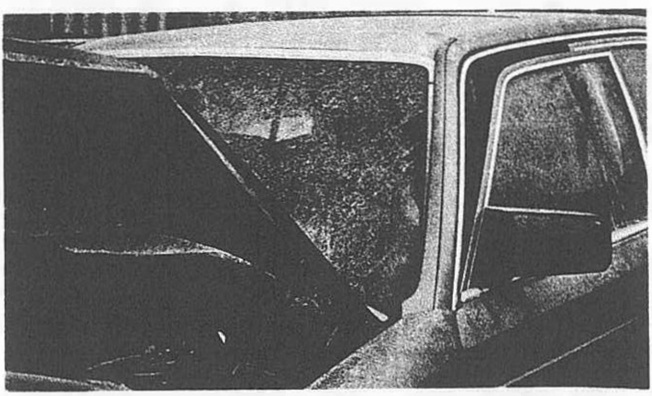


Fig. 4: Detail of the Mercedes-Benz 500 SE (case no. 2).

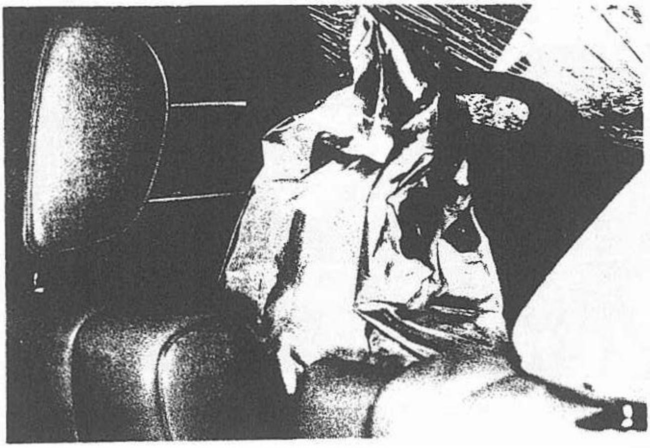


Fig. 5: Airbag and driver's seat in the Mercedes-Benz 500 SE (case no. 2).

Only after in-depth studies of crashes and injuries in airbag equipped cars are the injury mechanisms better understood. It is becaming clear that even minor lesions are not due to a simple pressure ofthe skin against a soft cushion, but are rather generated by a "slap" given by the unfolding restraint system.

More worrying is the possibility of corneal abrasions caused by the airbag, not only for the chance of visual impairment and expensive therapy, but of course also because this kind of lesion is inflicted to a body area that would have remained intact without airbag intervention. Even more severe ocular injuries have been reported, with corneal edema, hyphema, retinal dialysisand detachment. An upper cervical spine fracture has been described, as have finger lesions, both from direct loading and from thermal injury.

The occurrence of severe and fatal lesions in airbag crashes is rare, and for what we know in literature has always been associated with extensive damage to the occupant compartment.

However, the cases we describe in this paper share a common feature: they involve cars without passenger compartment deformation, or with only minimal

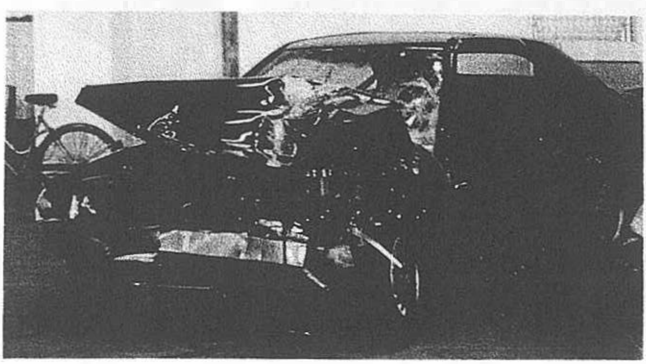


Fig. 6: Anterior view of the Mercedes-Benz 300 CE (case no. 3).

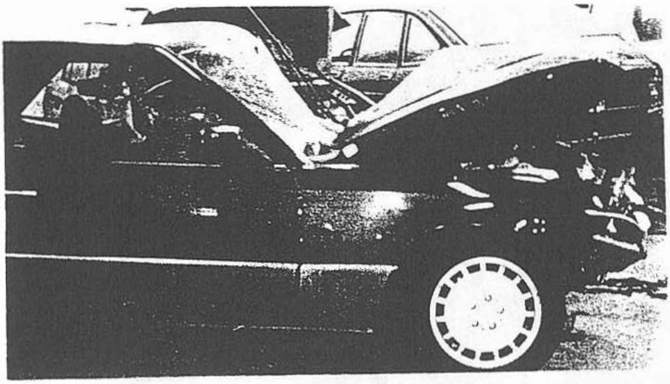


Fig. 7: Right lateral view of the Mercedes-Benz 300 CE (case no. 3).

intrusion. In fact, the lesions suffered by the victims may be attributed to airbag loading rather than to rigid car components.

Case no. 1 (Mazda MX-5) is rather intriguing, as it resembles a seat belt syndrome even though we are absolutely sure that there was no seat belt worn. It can be looked at as an extreme case of "occult injury", in which the free interval was very tight and the lesion was particularly severe.

From a pathogenetic point of view, it is well known how mesenteric laceration may be attributed, especially if near to the Treitz ligament, to a deceleration force applied to a structure that has only one possible movement. In this case, a rebound mechanism explains both the abdominal lesion and the described deformation of the steering wheel rim.

The pattern of lesions in our case no. 2 (Mercedes-Benz 500 SE) may confirm that a deceleration component plays an important role in severe airbag trauma. While, in fact, the group of rib fractures is compatible with direct loading, the lesion to the right atrium seems to be related to a torsional movement

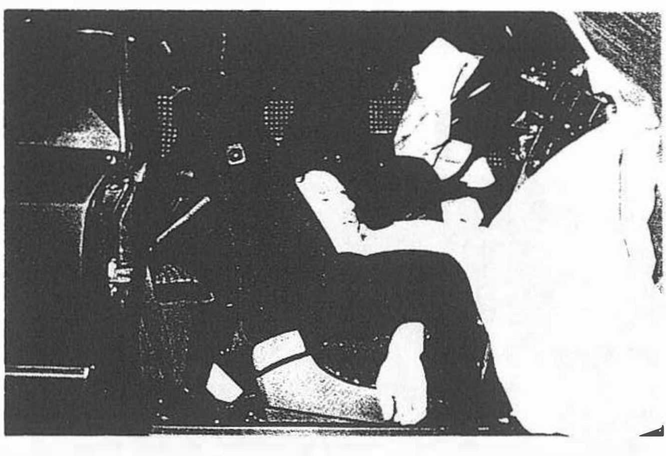


Fig. 8: Crash scene with the right passenger; both the airbags of the Mercedes-Benz 300 CE are visible (case no. 3).

of the heart, that is almost suspended in its position by the mediastinum vessels and the pericardium. If we consider that this is one of the most thin muscle walls in the heart region, it is possible to understand how it can be damaged by a sharp deceleration force without direct contusion.

It is important to note that a rupture of the right atrium related to airbag deployment has already been reported in the literature, in a crash whose victim survived.

In case no. 3 (Mercedes-Benz 300 CE), no autopsy was required by Authorities for the dead passenger. An external examination was performed by a not specialized physician, and therefore valuable information has been lost.

From the photographs taken by Police, the unbelted occupant was dead on scene. The absence of blood around his nose and mouth suggests an immediate breathing stop and therefore a sudden death.

The right arm is notably fractured. Even if it could be possible to hypothesize a non-traumatic cause of death, such as a cardiac arrest due to the fright of the accident, the occurrence of the arm fracture is a clear marker of something very violent. Moreover, a possible self-protecting manoeuvre (raising an arm to protect the head and face) could result not only in fracture of the limb by the inflating airbag, but also in compressing it against the thorax, concentrating a strong pressure on a narrow zone.

The driver himself of case no. 3 shows a complex of lesions that may be attributed to airbag loading; he was unbelted. The finding of intrahepatic hematoma suggests a "low" profile of loading, that is contrasting with the evident upward dislocation of the steering wheel.

The lesions described in our cases are very close to what has been observed on anesthesized animals in more or less extreme experimental conditions. However, we do not regard these cases as extreme or absolutely rare; in one issue of NHTSA bullettin a Mercedes-Benz with a deformation pattern comparable to case no. 3 has been reported as a success case.

In all our cases seat belts had surely not been worn. Only in case no. 2 (Mercedes-Benz 500 SE) the unbelted condition of the driver has to be considered as highly probable, but not certainly proven, because we had not been allowed to disassemble the seat belts themselves.

- Direct loading by the inflating airbag, at full surface or angled;
- Direct loading by the inflating airbag, with interposition of arms or objects;
- Contact with steering wheel despite the airbag;
- Secondary thoracic perforations by broken ribs;
- Visceral lesions caused by deceleration (i.e., inertial loading);
- Transmission of pressure waves to viscera *(hypothetical)*;
- Burning from hot gases;
- Chemical injury to hands or eyes.

Table II: Possible mechanisms of airbag lesions, according to literature and clinical observations.

In the case no. 1 (Mazda MX-5), the not wearing of seat belts has been demonstrated by a strange feature of the belt itself. In the lower part of the belt and near to the attachment bolt, the webbing has been sewn several times, in order to provide a loop that will be progressively broken under load. When this loop is about to open under stretching, a red warning *"Replace belt"* will appear (Figure 9). As this instrument was intact in the smashed car, it may be assumed that the seat belt has never been loaded during an impact. It seems very strange that a high-tech car could fit a devicethat will only assure some more centimetres of slack during an impact - something like a "post-tensioner".

Only in one case (Mazda MX-5) the steering wheel was found in a slightly rotated position; this could however be due to post-crash manoeuvres in towing the damaged car. That steering wheel is also the only one with appreciable deformation (10° bent at the lower side).

None of the described cars was initially marketed in Italy: the two Mercedes came from Switzerland and Germany, and the Mazda from the Netherlands. The Mazda MX-5 is not available with airbag in Italy, even as an option.

Immediately after the crash, the driver of the Mazda complained that *"the airbag did not work"*. As we found a completely deployed airbag and there is no proof of tampering of the airbag system after the crash, we may assume that this man had only partial information about how airbags work, and thought that it had to remain inflated even after the impact.

It is not possible, from our data, to comment upon the volume of airbags and its influence on the probability of lesions; however, it is instructive how the small airbag of the Miata allowed a deformation of the steering wheel rim.

For what concerns the pathogenesis of lesions, it seems now clear from literature that moderate lesions such as skin and corneal abrasions, facial bruisings, small contusions and hematomas are due to a "slapping" pattern rather than to violent contact between the occupant anf the airbag.

On the basis of our cases, it is possible to hypothesize on the mechanisms that may lead to out-of-position occupants and to airbag trauma.

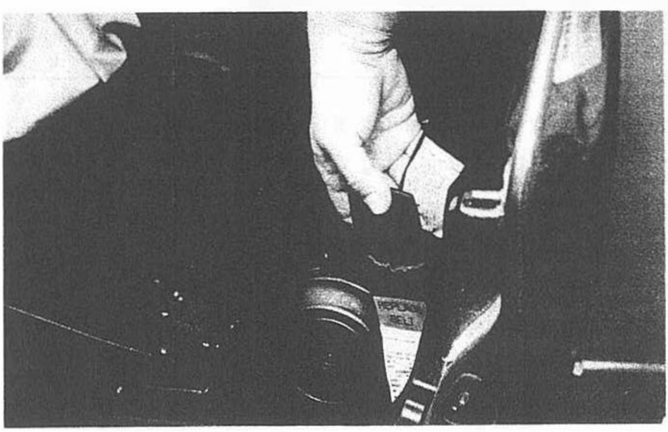


Fig. 9: Stress dampener on the Mazda MX-5 Miata (case no. 1).

We could recognise a group of pathogenetic patterns, as described in Table II; it could be possible also to hypothesize a mechanism of trauma due to transmission of pressure waves on parenchymatous visceral organs.

Other mechanisms of airbag lesions are possible, but are more related to misuse or reckless seating position. For instance, in Italy we observed the fatal case of a child travelling in the front right passenger's lap on a double-airbag equipped German-made roadster and beheaded in a low-speed crash.

Some of the injuries potentially due to an airbag may remain occult for some time, not providing any clinical symptom for a period ranging from minutes up to 48 hours ("free interval"). Therefore, at the time of the first medical diagnosis it could be highly dangerous to ignore the possibility of an occult abdominal injury, that could endanger life some hours after the accident. A more aggressive diagnostic approach could therefore save lives in such circumstances.

The problems of near-position and out-of-position occupants ought to be better identified in crash tests and simulation procedures. Particularly, some tests should include a modulated deceleration before the impact, to better simulate the movements of the passenger towards the dashboard.

The possible causes of out-of-position are reproduced in Table III.

It is questionable if passenger airbags should comply with the same principles of the driver's one, or if they substantially differ in their dynamics. Even if technology and deployment are more or less the same, passenger behaviour is less restrictive allowing for quitedifferent seating positions.

The driver maintains his arms at a distance equal to the diameter of the steering wheel, and the airbag will deploy within them: in otherwords, the driver is naturally on an "airbag aware" posture.

On the other hand, the passenger may assume more comfortable postures, such as crossing arms, or may look for objects around, or may raise arms to protect himself in an impending impact, assuming an "airbag hostile" posture. In these cases, and even for a belted passenger, the upper limbs may be reached by the airbag and compressed against the chest.

This mechanism, that may have operated in our case no. 3, could concentrate the pressure upon a very narrow surface, with possible focal rib fractures and penetration of fragmented bones into the chest.

An out-of -position body may act as an "external" tether, modifying the external shape of the bag, but it is highly feasible that the gas pressure may actually cause a rebound of the body, at least in near-position situations. In these cases, deceleration lesions could be possible and may involve parenchymatous viscera (e.g. liver) or partially mobile structures like mesentery, or mediastinum vessels.

Like seat belts, air bags cause minor injuries such as abrasions; unlike the seat belt, however, an airbag does not cause injury through direct loading of the body on pre-existentcontact points, butthrough contact in the deployment stage or immediatey following it. Moreover, some patterns of lesion involve body regions that would likely remain unhurt, such as ocular injurie.

The temperature of gases itself may cause harm, while some cases of chemical intoxication are reported in the literature.

In seat belt related injuries, the dissipation of energy depends mainly on the kinetic energy associated with the impact, and therefore is substantially speed-dependent, sometimes involving belt slack or submarining. In air bag lesions the kinetic energy is provided mainly by the restraint system itself; therefore, the outcome is more a function of other variables such as occupant position, and may be very serious even at low speed.

Permanent (steady): • Short stature; • Advanced driving posture; **Dynamic (pre-impact):** • Braking or slippery before first impact; • First impact below threshold or not frontal; • Voluntary movements, e.g. trimming a car stereo or searching objects; **Partial (only some body portions are mispositioned):** • Hands in the middle of the steering wheel ("claxon reflex") • Comfortable passenger postures, e.g. stretching legs or crossing arms; • Self-defense posture, such as raising arms to protect head and face.

Table III: Possible causes of out-of-position movements.

From a dynamic standpoint, it is possible to conceive the activation of an airbag system as a flow of events between a near-collision and the outcome of the crash (Figure 10). An ideal model is potentially biased by a constellation of interferences, that might also interact with each other.

With this view in mind, it could be possible to add "smart" features to an airbag, for instance feeding its processor with data on speed, acceleration, belt wearing, distance from occupant's body and so on, in order to avoid interference with optimal performance. Such a system should decide not only if it should be activated, but also what level of activation is needed to achieve the maximum compliance with a given situation and a given person.

It is not clear how an explosive-powered device such an airbag could be triggered in order to differentiate responses to different inputs; however, a modulation of airbag deployment would be particularly important for threshold impacts, around the range of activation of the system.

In the worst hypothetical situation, a vigorous braking at city speed followed by a crash could result in a 200 km/h impact of the inflating airbag against an unrestrained passenger; in this way, a survivable crash could become in a fatal one. Considering the belt use rate in city traffic, this situation should occur in a high number of cases, especially with small cars, for instance like Ford Fiesta and Volkswagen Golf, which in the near future will have full frontal airbags, that are more likely to be used in urban driving than large cars, and more frequently by female drivers, that generally seat more forward than male drivers.

Of course, an algorithm of "smart" airbag activation should consider a range of current kinematics of car occupants, and should be interfaced with a state-of-the-art seat belt as well as with the overall deceleration pattern of the car.

From our experience, it seems very dangerous to allow airbag inflation when it is not sure there is enough space between the occupants and the deploying airbag.

From this point of view, also the introduction of side airbags should be carefully studied in order to prevent dangerous contacts with the chest, that

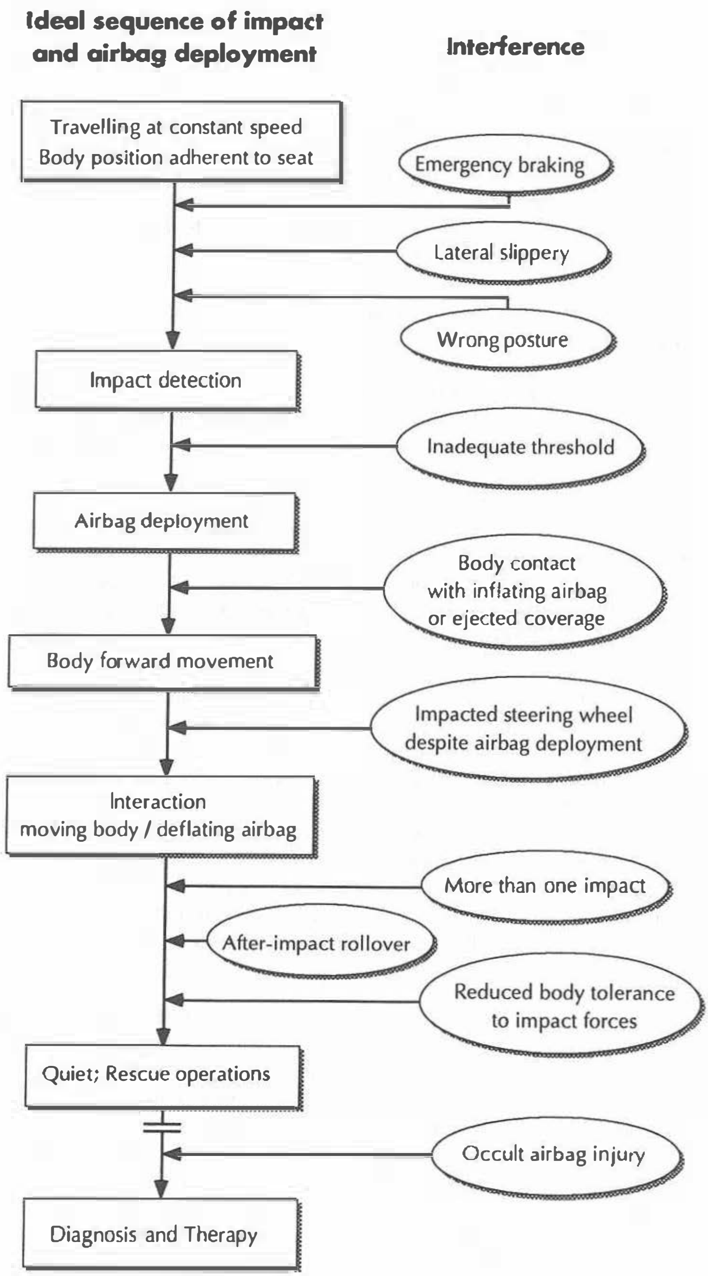


Fig. 10: Ideal sequence of impact and airbag intervention in a frontal impact, and possible interferences.

would occur even to a belted occupant if the car, for instance, had a slope before impacting an obstacle with its side.

Some forensic aspects of these cases deserve further consideration.

With regard to accident reconstruction, it will be difficult to evaluate pre-impact braking if the car is equipped with ABS or similar systems, as usually for an airbag-equipped.

For what concerns responsibility, it is clear how restraint system or cars manufacturers might be directly involved, if such fatal airbag cases should replicate. In at least two of our three fatal cases the belts were surely not worn; however, there is little doubt that the lethal injuries were due to the direct impact and loading by the airbag itself.

It is mandatory to provide better information to car users, by clear and visible warnings not confined to inclusion in the car users' manual or inside the sunvisor.

What is worse, some current advertisements and articles on newspapers and magazines are characterising the airbags as the ultimate safety dispenser, without giving adequate informations to the need to wear seat belts even if an airbag is provided. This may generate a common feeling that airbags alone are a warranty to survive, thereby decreasing the belt wearing rate.

Manufacturers have a responsibility here to provide appropriate information about seat belt and airbag interaction.

In Italy, the use of seat belts has always been very low, even after usage legislation in April 1989; therefore, it is not surprising that all our cases deal with unbelted occupants. Moreover, driving or travelling in an airbag equipped car may give a presumption of safety, thus lowering again the wearing rate. With this scenario, marketing a safety device, such as the airbag, that requires belt buckling must be carefully done in countries with low buckling rates.

Drivers too have a responsibility, if an unbelted passenger suffers airbag lesions, at least in those countries which define the driver as responsible for the belt wearing inside the car, as is the case in Italy.

Another group of forensic problems may regard the behaviour of the rescue teams and the medical treatment at the Casualty ward. All the personnel must know that in some conditions airbags may give occult visceral injuries.

The treating team must be able to recognise their first clinical symptoms, providing an adequate observation period for incoming patients.

Conclusions

Even if it could be rash to question the overall effectiveness of airbags from these case reports, it is hard to accept that a safety measure, even if supplemental, might kickback with so dangerous side effects.

We perceive that airbags, being born to protect mainly unrestrained occupants in low-speed (limited at 55 mph) and large size vehicles, need adjustments to fit low- or middle-size, cars travelling at European speeds.

The face bag could obviously be less dangerous, or more precisely could have less probabilities to impact a displaced body. Unluckily, as in one of the case we presented, it may not "fill" enough the survival space to prevent contacts with the steering wheel or forward projection.

To completely eliminate the danger of severe damage to a mispositioned body, we think that some smart functions have to be added to the logic of airbag deployment: for instance, the deployment could be related to variables like speed, peak deceleration, detection of masses in the survival space, biometric features of the occupant, belt wearing or not.

The mechanisms that lead to the fatal consequences in our cases may replicate in the future, particularly in crashes with unbelted people and decelerations before the impact phase.

Many efforts have been devoted to the increase of seat belt use, but nevertheless an appreciable percentage of drivers and passengers still do not buckle up. In these conditions, the risk of severe airbag lesions is not acceptable.

Compared to seat belts, airbags appear now to be at the "lap-only" stage. Further research and experimentation is needed; our preliminary experience with airbag lesions shows that crash tests themselves have to be improved, in order to provide better informations and help reducing the fatal danger of near- and out-of-position movements.

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Discussion of Papers by Huelke et al and Zuppichini et al

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Whenever a safety-related development is incorporated into the vehicle fleet, it is fundamental that the actual real world crash performance is evaluated. The introduction of airbags into cars around the world is taking place at such a rate that within a few years the majority of vehicles in the United States will have both driver and passenger side airbags. Japan and Europe, Asia and Latin America will follow later.

The introduction of a safety device on this scale is analogous to the introduction in the pharmaceutical world of a major new drug. When such a drug is developed, great efforts are made to evaluate effectiveness and side effects. Those efforts cover not only laboratory testing and evaluation, but systems are put in place to provide information on actual clinical performance and contraindications. In contrast the systematic evaluation of safety related items in automotive design is relatively under researched almost everywhere in the world. Field studies are not an integral part of the process of design and development or rulemaking; which is why ad hoc studies such as the two reported here are of particular interest.

The upper extremity injuries from airbags reported by Huelke et al illustrate the importance of real world studies. Laboratory testing with dummies does not have the capability of predicting these injuries. The trauma reported are clearly a function of arm positions adopted by the general population and do not appear to be susceptible to redesign of the airbag. They represent one particular characteristic of the general range of postures, sitting positions and anthropometric variations seen in the general population in cars.

Similarly the case studies reported by Zuppichini et al represent the first feedback from the real world of airbag cars in Europe. Although only three crashes are described, they raise some points of general interest.

It is important to know the specific characteristics of occupants as far as is possible post-crash. Height and weight are important, and together with seat position give some insights into how occupants are located relative to the airbag. In the general population, height and weight are by no means coincident, and with airbags the question of the chest and abdomen being within the deployment zone of the airbag may well be an important feature of some of the thoracic and abdominal injuries which are reported.

How the actual population sit in cars has been researched recently (Parkin, Mackay, Cooper, 1993) to show that small females particularly sit close to the steering wheel and thus sit within the deployment zone of many airbags. A greater recognition of real occupant positions may well lead to modification of current airbag characteristics.

Presently airbags in the United States are optimized around the two conditions of the unrestrained dummy in the 30 mph FMVSS 208 flat barrier test, and the 35 mph condition of a belt restrained dummy in an NCAP test. This leads to a relatively large, relatively aggressive airbag because it must manage all the kinetic energy of the otherwise unrestrained dummy. The European "facebag" on the other hand is designed with the assumption that the occupant will be wearing a seat belt, and it is thus a smaller device, imparting less energy into the occupant.

In the United States the designer is in a particularly invidious position because currently seat belt use in crashes is barely greater than 50%. Therefore the claims of the unrestrained and the restrained populations are roughly equal, but different. This must lead to the conclusion that efforts to raise the levels of belt use in North America still have top priority.

Once belt use is high, the arguments in favor of less aggressive airbag systems will develop and perhaps will eventually see a convergence in airbag design around the world.

These studies also illustrate another aspect of occupant position, particularly for the passenger. If pre-impact braking occurs, an unbraced passenger even if wearing a seat belt can move significantly immediately prior to impact and thus be exposed to high energy airbag contacts. Current vehicle sensitivity levels for retractor locking might well be reconsidered to diminish this situation for the belted passenger, but for the unbelted passenger it is difficult to see what can prevent such a person being out of position.

Thus the lessons of these interacting field accident studies are that in the real world people vary enormously, they adopt a wide range of positions and they have a wide variation in response to crash loads. One must expect there to be a great range of outcomes for a given crash circumstance and therefore generalizing from small samples is often inappropriate. Such studies however are the vital first indicators of potential limitations of airbag effectiveness and should provide useful pointers for future research both in the laboratory and the field.

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