

The effectiveness of side airbags in preventing thoracic injuries in Europe

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Abstract. During the last 5 years, the number of cars fitted with side airbags has dramatically increased. They are now standard equipment, even on many smaller cars or less luxurious vehicles. While some side airbags offer thoracic protection alone, there are those that combine thoracic and head protection (of which most deploy from the seat). Other systems employ separate airbags for head and thorax protection, which are designed to be effective noticeably in a crash against a pole.

This paper proposes an evaluation of the effectiveness of side airbags in preventing thoracic injuries to passenger car occupants involved in side crashes. First, the target population (who can take benefit of side airbag deployment and in what circumstances) is defined. Side airbags can be especially effective in cases of impacts on the door with intrusion at a certain impact speed. Then, an example case of a side impact with side airbag deployment is given where side airbag deployment is thought to have had a positive effect on injury outcome. A further case is presented where the impact configuration is likely to have reduced the effect of side airbag deployment on injury outcome. Finally, the estimation of side airbag effectiveness (in terms of additional occupant protection brought exclusively by the airbag) is proposed by comparing injury risk sustained by occupants in (more or less) similar cars (fitted or non fitted with airbags) because, during these years, car structure, and side airbag conception have considerably evolved.

In-depth accident data from France, the UK and Germany has been collected. Out of 2,035 side impact accident cases available in the databases, we selected 435 occupants of passenger cars (built from 1998 onwards) involved in an injury accident between year 1998 and year 2004 for EES (Energy Equivalent Speed) values between 20km/h and 50 km/h. The occupants, belted or not, were sat on the struck side, whatever the obstacle and type of accidents (intersection, loss of control, etc.). For multiple impact crashes, the side impact is assumed to be the more severe one. Passengers cars were fitted with (96) or without (339) side airbags. Most of the potential risk explanatory variables were correctly and reliably reported in the databases (velocity – impact zone – impact angle – occupant characteristics, etc.).

The analysis compared injury risks for different levels of EES and different types of side airbags. A logistic regression model was also computed with injury variables (such as thoracic AIS 2+ or AIS 3+) as the dependant variable and other variables (including airbag type and EES) as explanatory injury risk factors.

Results revealed statistically non-significant reductions in thoracic AIS 2+ and AIS 3+ injury risk in side airbag equipped cars in the impact violence range selected (odds ratio between 0.84 and 0.98 depending on types of airbags).

The results are discussed. The non-significance is assumed to be due to a low number of cases. Statistical analysis for head injuries was not possible due to the low number of accident cases with passenger cars fitted with head airbags in the databases. Moreover, the discrepancies between the data coming from different countries (especially calculation of EES) might have introduced instability in the analysis.

INTRODUCTION

During the last 5 years, the number of cars fitted with side airbags has dramatically increased. This went with the new regulation governing design of vehicles for side impact crashes introduced in the European Union in 1996 (UNECE R95). They are now standard equipment, even on many smaller cars or less luxurious vehicles. While some side airbags offer thoracic protection alone, there are those that combine thoracic and head protection (of which most deploy from the seat). Other systems employ separate airbags for head and thorax protection which are designed to be effective, noticeably in a crash against a pole.

The effectiveness of side-mounted airbags in real-world accidents has already been studied a few times in the literature, though much later than frontal airbags. These studies followed biomechanical

studies (experiments and numerical simulation) on side airbag effects, especially for out-of-position occupants and restrained children (e.g. Prasad et al, 2001; Tylko et al, 2001, Schneider et al., 2005, Dalmotas et al., 2001). Evaluation studies started with anecdotal case studies and description of side crashes involving cars equipped with side airbags. For example, Kirk and Morris performed an interesting initial case review (47 UK cases) that details the conditions under which airbags might or might not be effective (Kirk and Morris, 2003). Each case with side airbag deployment was assessed to determine where deployment had no influence on occupant injuries (due to crash type or low crash severity); crash severity was too high to expect injury mitigation; deployment prevented injury; or where there was a possible causal relationship between the injuries to the adjacent occupant and deploying side airbag. However, some crashes were too complex to assess potential benefit. The study concluded that side bag deployments are preventing injuries in the real world. However, deployment is sometimes taking place in cases where it would not be expected (especially when the deployment is on the non struck side and in some frontal impacts). In some cases, the crash severity exceeds the protection capabilities of the airbag systems. On the other hand, a few cases presented injuries that might have not occurred without bags, so further consideration should be given to possible injury mechanisms.

Then, a series of real-world studies based on field accident data started. After Bauer et al. (Bauer et al., 2000), Yoganandan et al. analyzed field data on side impact injuries in vehicles equipped with side airbags (i.e. 68 cases with side airbag deployment in side crashes, drawn from the U.S. National Accident Sampling System). They mainly described impact cases with variables such as occupant age, gender, height, weight, delta-V, injured body regions, number of injuries and injury severity. This preliminary study was followed by another one comparing head injury outcomes sustained by occupants involved in side impacts in cars, light trucks and vans equipped with or not equipped with side airbags (whatever types) in a matched-pair design (Yoganandan et al., 2005). Out of the 61 raw cases with side airbag deployments selected in the NASS files from 1994 onwards, only 23 had head injuries. Controls (same make model and year of the vehicle but without airbag) were only 17. Consequently, a case control analysis was not possible. The authors suggested that the separate system of torso and curtain side airbags appears to offer improved protection to the head though.

In this phase of side airbag effectiveness exploration, all authors underlined that findings based on small samples should be reinforced with additional data in the future.

Then evaluation studies turned towards the comparison of injury risk sustained by occupants involved in side crashes in cars fitted with side airbags versus cars without side airbags. In case of fitting, some studies distinguished torso airbags and head airbags and mounting locations (door, seat, cant rail). For example, McGwin et al. analyzed 1997-2000 nearside impact data using US NASS data and concluded that front seat occupants of vehicles fitted with side airbags had a risk of injury similar to occupants of vehicles without side airbags (McGwin et al., 2003). However, the authors combined cars fitted with side airbags as standard and as optional equipment and did not make any distinction between types of side airbags. This could have introduced bias in the analysis.

Morris and al. used UK national accident files and also in-depth accident investigations to determine how injury outcomes have changed between cars manufactured pre 1993 and newer cars manufactured post 1998 (Morris et al., 2005). The results seem contradictory: seriously injured and killed rates for belted struck side front occupants are lower in newer cars compared to older but the rate of serious chest injury is higher in the sample of cars with side airbag deployment (25%) than the sample of cars with no side airbag deployment (10%). They then suggested good benefits from regulation in reducing struck side injury outcomes. Results about side airbag effectiveness based upon a sample of 287 occupants involved in struck-side crashes suggested that cant rail airbags would be effective in preventing serious head injuries, that door-mounted and seat-mounted airbags would not prevent AIS2+ head injuries, that door-mounted airbags would reduce chest AIS2+ injuries but that seat-mounted would not reduce AIS2+ chest injuries. However, cars with side airbag deployment were compared to cars without side airbag deployment (including cars fitted with and cars not fitted with side airbags), which is suggesting a bias in crash severity in the two samples (crashes with no airbag

deployment are less violent). These inconsistent findings led the authors suggesting that out-of-position occupants could play a role in the injury mechanisms, which should then be regarded carefully.

The only published paper, to our knowledge, studying the effectiveness of side airbags in preventing fatalities with an epidemiological design and statistical analysis is the one by Braver and Kyrychenko (2003) using data from the U.S General Estimates System and the Fatality Analysis System. This study computed the rate ratios for deaths per nearside collision for model years 1997-2002 during 1999-2001 for side airbags designed to reduce injuries to both torso and head and those designed only to prevent torso injuries. Weighting this data to a national level resulted in an estimated 22,289 drivers in passenger cars with head /torso side airbags and a further 45,640 with torso only side airbags fitted. Out of these, there were 35 near-side driver deaths in cars fitted with head/torso bags and a further 105 when torso only bags were present. Results show a decrease in driver fatality risk in near-side crashes by 45 % in passenger cars equipped with head-torso airbags and by 11 % in cars fitted with torso airbags.

Finally, the last study available is the one by Otte and Richter (2006). This study aimed at analyzing and comparing injury patterns of car occupants after side impacts in cars fitted or not fitted with side airbags. Out of 9,865 accident cases documented in the GIDAS database between 1999 and 2004, 71 concerned passenger car occupants involved in side crashes with side airbag deployment, seated on the impact side and 266 concerned occupants involved in the same type of crash but without side airbag deployment. Delta-V in these crashes ranged from 5 to 50 km/h. The analysis consisted of comparing the statistical distributions of a few parameters for both groups and to run a case by case complementary investigation. The authors observed some noticeable differences in the two groups (large cars are more likely to be equipped with side airbags, side impacts with deployment are more frequently located in the doors, delta-V's are higher for cars with side airbags, the opponent is more frequently a passenger car for cars with side airbags). Consequently, the descriptive statistical analysis was not able to determine whether side airbags show a protective effect. This is also mainly due to the complexity of the types of crash under study. A multivariate analysis concluded with similar results. On the other hand, an in-depth case-by-case analysis, based on statements made by an experienced accidentologist showed that in 40 % of the deployed side airbag cases, the injury outcome would be possibly lesser than the one expected, taken into consideration the parameters of the crash and impact. The authors concluded that *the protective effect of the side airbag is difficult to assess from the accident data*. This is due to very different impact situations and very different relative movements of the car occupants. As a matter of fact, results coming out from statistical analysis and in-depth analysis seem to be contradictory.

This paper proposes an evaluation of the effectiveness of side airbags in preventing thoracic injuries to passenger car occupants involved in side crashes. First, the target population (who can take benefit of side airbag deployment and in what circumstances) is defined. Side airbags can be especially effective in cases of impacts on the door with intrusion at a certain impact speed. Two case examples illustrate how changes in crash configuration may have an influence on side airbag performance. Finally, the estimation of side airbag effectiveness (in terms of additional occupant protection brought exclusively by the airbag) is proposed by comparing injury risk sustained by occupants in (more or less) similar cars (fitted or non fitted with airbags) because, during these years, car structure, and side airbag conception have considerably evolved.

METHOD

Data Sources

Three kinds of sources have been used:

- The French and the UK road injury accidents national census has provided an estimation of the population targeted by side airbags by counting the annual number of fatalities and seriously injured casualties as passenger car occupants in side impacts. Then the LAB in-depth accident database has been used in order to get the repartition of these casualties according to their location: impact nearside or far side. It is indeed assumed that airbag can protect from intrusion but cannot protect occupants located in the opposite side of the impact.

- Then, CCIS (Co-operative Crash Investigation Study) cases (UK) were used in order to conduct case analyses and further specify, amongst the side impact crashes, those for which a side airbag is likely to be effective and those for which it isn't. Previous studies actually suggested that there is a quite large variety of side impacts, due to variety of delta-V's, impact angles, body motions, obstacles, location of impact. Two examples from this work are given in this paper.

- Finally, in-depth accident data from France (LAB database), the United Kingdom (CCIS) and Germany (German In-Depth Accident Study, GIDAS) has been compiled to conduct the risk and effectiveness analysis. 2,035 fully documented side impact accident cases were collected from 3 institutes in the 3 countries (Laboratory of Accidentology, Biomechanics in France, Vehicle Safety Research Centre in the UK and Medical University Hannover in Germany). Out of these 2,035 cases, we retained only 435 occupants of passenger cars (front and rear). This restriction is due to the selection of relevant cases only:

- Cars built from 1998 onwards involved in an injury accident between year 1998 and year 2004 in order to compare only newer cars.

- EES¹ values between 20km/h and 50 km/h as we expect absence of relevance of side airbags at low and very high speeds.

- The occupants belted or not, were sitting on the struck side, whatever the obstacle and type of accidents (intersection, loss of control, etc.).

- For multiple impact crashes, the side impact is assumed to be the more severe one.

- Just a few cases were available with head airbags or combined head and thoracic airbags, Therefore, the analysis is mainly focused on thoracic airbags and thoracic injuries.

Data from the three countries were combined into a single file for analysis. Simple descriptive statistics were not computed as the varying nature of the case selection criteria would not result in meaningful data descriptions. Risks of injury were calculated for two severity levels of thorax injury and the data was modelled using multi-variate logistic regression to control for a range of explanatory variables (velocity – impact zone – impact angle – occupant age and gender, etc.) and to estimate the odds ratios of side airbag injury reduction.

¹ It must be underlined here that the availability of EES in the 3 different databases is the major reason for the small size of the sample. For more than 30 % of the side crashes this value is not available. EES is actually difficult to estimate in side crashes. Moreover, in some cases, one prefers estimating the closing speed, the speed at impact or the ETS value. However, as the three databases used offered more consistency and the largest number of cases for EES, we retained this parameter as a marker of violence of the impact.

RESULTS

Target Population

National data provides the overall magnitude of side impacts. For example, in France, side impacts account for about 25 % of fatalities (front and rear seats) and 18 % of seriously injured casualties in passenger cars. In the UK data 41% of fatally injured occupants died in side impacts and 37% of seriously injured casualties received their injuries in side impacts. 40 % of the French fatalities (respectively 60 % of those seriously injured) occur against another car, one third (respectively 30 %) against a fixed obstacle and 25 % (respectively 10 %) against a light or heavy truck.

70 % of the fatalities and 50 % of the seriously injured casualties in side impacts occur on the struck side with intrusion. Consequently, in France, 17 % of overall fatalities ($70 \% * 25 \%$) and 9 % of overall seriously injured casualties ($50 \% * 18 \%$) are the target population for side airbags, which are supposed to work for occupants seated against the struck door. This calculation was not done for either Germany or the UK, but is supposed to give close estimations.

Case Analysis

While statistical analysis and models can be used to derive a generalised view of accident data case by case reviews provide a complementary role. They are able to produce a fuller understanding of the real-world event and help to define key factors for use in subsequent modelling. An overall review of cases can help to define the most valuable selection criteria for cases to be included in the model and to avoid outliers. They can also provide a qualitative view of the limits of protection with side airbags. An additional expert case review can also indicate injuries that would probably have occurred without side airbags and identify potential airbag induced injuries.

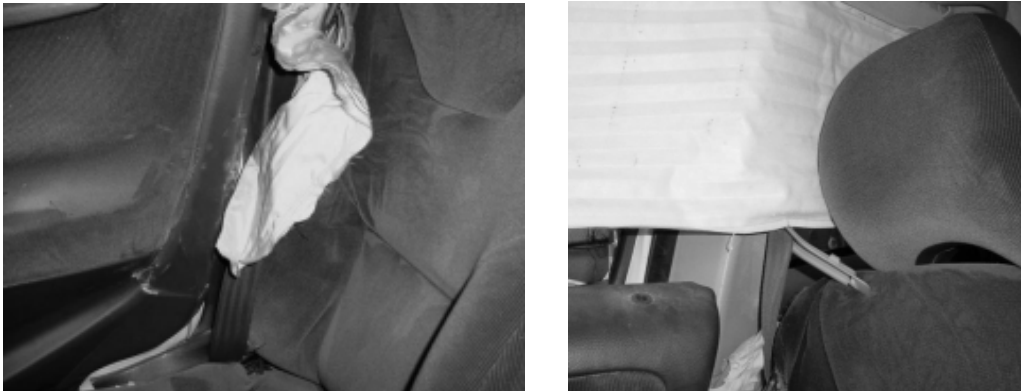
The CCIS database was searched for examples of cases of medium to high severity side impacts with low severity occupant thoracic injury, cases where side airbag deployment may have been effective for injury prevention and a higher injury outcome may have been expected. Two examples of the cases found are presented here.

Case 1. In this selected case a passenger car was struck in the side by a passenger car of similar size. The direction of force was between 3 and 4 o'clock (90 to 120 degrees) on the right side (this was a right hand drive UK car). The EES was estimated as 40 to 45 km/h with an overall maximum crush of 46 cm. The intrusion at the driver's position was measured as 34cm at both the base of window and pelvic levels, in the centre of the door.



Figures 1 & 2. Case 1 - side impact damage

Both the thoracic (seat mounted) and head curtain side airbags deployed at the driver's position. The belted 34 year old male driver sustained just slight AIS 1 injuries, a laceration to the right hand, graze to the right elbow and clear bruising to the right lateral thigh. The steering wheel airbag did not deploy.



Figures 3 & 4. Case 1 - Intrusion and deployed side airbags at driver's position

Case 2. A passenger car lost control in snow conditions, leaving the road and colliding with a tree. The direction of force of the impact was 4 o'clock (120 degrees) on the right side (this was a right hand drive UK car). The EES was estimated as 50 km/h with an overall maximum crush of 67 cm. The intrusion at the driver's position was measured as 27cm at the base of the window and 35cm at the pelvic level, in the centre of the door. It can be seen though, by comparing the intrusion patterns in cases 1 and 2, that in fact the crush profile in case 2 is more forward on the driver's position and spread over a smaller area than the car to car impact shown in case 1.



Figure 5. Case 2 - Side impact damage

The combined thoracic and head side airbag deployed at the driver's position. The belted 32 year old female driver sustained just slight AIS 1 injuries, lacerations to the right side of the head and face, lower right leg and right hand, and contusions to the right knee, lower right leg, lower left leg, right upper arm, right posterior chest and central anterior chest. The steering wheel airbag did not deploy.



Figures 6 & 7. Case 2 - Intrusion and deployed side airbags at driver's position

Risk Analysis

435 occupants of passenger cars (front and rear seats) constituted the sample. 96 passenger cars were fitted with side airbags and 339 were not. As just a few cases were available with head injuries, the analysis was focused on thoracic injuries only. The analysis consisted first of cross-tabulations comparing injury risks for different levels of EES and different types of airbags (no side airbag, thoracic only, combined thoracic and head side airbag). Table 1 shows the distribution of thoracic injuries according to EES, type of airbag and severity. Although it might be expected that the groups of deployed airbag cases might have a higher collision severity than the non-deployed Table 1 demonstrates that the group of deployed torso airbag cases sustained an almost identical collision severity distribution as the no airbag cases. The combined head and torso airbag cases tended to be involved in higher severity collisions.

Table 1 clearly shows that:

- The majority (54%) of the crashes in the sample occur at the lowest sampled level of severity (between 20 km/h, the lower threshold in the selection criteria, and 30 km/h).
- The division of side airbags between thoracic airbags and others results in small sub samples, and even smaller sub samples when broken down by EES, which makes the comparison of injury risks broken down by airbag types difficult.
- the severity of injuries increase with EES, which comes as no surprise.
- the distribution of thoracic injury severity within a certain range of EES is apparently not dependent on the presence of a side airbag (regardless of the type).

No Side Airbag	Thoracic Injuries AIS 0-1		Thoracic Injuries AIS 2+		All	
	N	%	N	%	N	%
21-30 km/h	156	81%	36	19%	192	57%
31-40 km/h	65	69%	29	31%	94	28%
41-50 km/h	24	45%	29	55%	53	16%
All	245	72%	94	28%	339	100%

Thoracic Side Airbag Deployed	Thoracic Injuries AIS 0-1		Thoracic Injuries AIS 2+		All	
	N	%	N	%	N	%
21-30 km/h	21	81%	5	19%	26	59%
31-40 km/h	9	69%	4	31%	13	30%
41-50 km/h	2	40%	3	60%	5	11%
All	32	73%	12	27%	44	100%

Combined head and torso Airbag Deployed	Thoracic Injuries AIS 0-1		Thoracic Injuries AIS 2+		All	
	N	%	N	%	N	%
21-30 km/h	13	77%	4	24%	17	33%
31-40 km/h	16	67%	8	33%	24	46%
41-50 km/h	5	46%	6	55%	11	21%
All	34	65%	18	35%	52	100%

All	311	72%	124	29%	435	100%
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Table 1. Distribution of thoracic injuries according to EES, type of side airbag and impact severity

This first analysis was considered not sufficient because it did not provide us with a statistical multivariate estimation of the effectiveness of side airbags. This multivariate analysis is systematically required when there is a suspicion of confounders between the groups to be compared (Hosmer et Lemeshow, 2000; Page, 1998). We then computed a logistic regression with injury variables (i.e. thoracic injuries AIS 2+ or AIS 3+) as the dependant variable and other variables (gender, age, airbag type and EES) as explanatory injury risk factors. Results showed a reduction in thoracic AIS 2+ and AIS 3+ injury risk in side airbag equipped vehicles in the EES 20km/h to 50 km/h range, i.e. an odds ratio of 0.83 for thoracic side airbags compared to no side airbag (table 2). However, even positive, these estimations are not statistically significant (large 95 % confidence intervals).

Table 2 also shows that gender has a large but non-significant effect on injury outcome, males were 34% more likely to sustain AIS 2+ torso injuries and 25% more likely to sustain AIS 3+ injuries compared to females. Increasing age and collision severity were also both significant factors in determining injury outcome, both being related to increasing risks of injury.

Logistic Regression : Dependant Variable : Thoracic Injuries AIS 2+				Logistic Regression : Dependant Variable : Thoracic Injuries AIS 3+			
N= 375 (111 AIS 2+) AIC : 411 SC : 438 -2 Log L : 397				N=375 (102 AIS 3+) AIC : 404 SC : 431 -2 Log L : 390			
	Odds ratio	Min. Limit (95 %)	Max Limit (95 %)		Odds ratio	Min. Limit (95 %)	Max Limit (95 %)
Gender <i>Reference : Female</i>				Gender <i>Reference : Female</i>			
Male	1.34	0.80	2.23	Male	1.25	0.75	2.10
Age	1.03	1.02	1.04	Age	1.03	1.01	1.04
Type of Bag <i>Reference : no bag</i>				Type of Bag <i>Reference : no bag</i>			
Other bag deployed	0.98	0.49	1.97	Other bag deployed	0.90	0.44	1.85
Thoracic Bag Deployed	0.83	0.37	1.86	Thoracic Bag Deployed	0.83	0.37	1.88
EES <i>Reference : 21-30</i>				EES <i>Reference : 21-30</i>			
31-40 km/h	1.91	1.09	3.33	31-40 km/h	1.92	1.10	3.37
40-50 km/h	5.82	3.06	11.07	40-50 km/h	5.68	2.99	10.79
Percent agreement : 74 % Percent disagreement : 25.7 % Percent tied : 0.4 % Pairs: 29 304 Somers' D = 0.48 Gamma = 0.48 Tau-a = 0.20 c =0.74				Percent agreement : 72.5 % Percent disagreement : 27.1 % Percent tied : 0.4 % Pairs: 27 846 Somers' D = 0.45 Gamma = 0.46 Tau-a = 0.18 c =0.73			

Table 2. Results of Logistic Regressions (Logit Models)

DISCUSSION

The effectiveness of side airbags in the real-world has been studied for about 5 years. It started with case reviews and then with attempts to determine with appropriate statistical methodologies whether or not an occupant involved in a near side crash sustains injuries with a lower level of severity in a car with a side airbag than in a car without a side airbag. All studies stated the difficulty to conduct such an effectiveness analysis, mainly because:

- the complexity and the variety of real-world side crashes were considerable. The examination of cases shows that in some cases there is no influence on occupant injuries (due to crash type or low crash severity) or crash severity is too high to expect injury mitigation. Additionally in some cases there is a possible causal relationship between the injuries to the adjacent occupant and deploying side airbag.
- the low number of side airbag fitted cars involved in side crashes as this feature is rather new, even though now largely fitted cars as standard equipment. Consequently, statistical analysis often ends up with contradictory, unexpected, non explainable or non significant estimations.
- the variety of side airbags types (thoracic protection only, thoracic and head, or thoracic and head separated) along with the difference in mounting on the door or the seat for thoracic side airbags. Consequently the injuries addressed are also varied. The statements for evaluation demand even larger samples.

Unfortunately, crash selection and the limited number of cases do not allow the estimation of effectiveness according to different types of side airbags for different crash configurations. Our result then holds only for thoracic airbags.

Case Analysis

In case example 1 it is thought likely that side airbag deployment has had a positive effect on thoracic injury outcome (and in fact head injury as well). This was a substantial side impact to the driver's area and only slight, AIS 1, injuries have occurred. This paper has not systematically investigated cases without side airbag deployment so cannot give a completely balanced view and suggest that thoracic injury would definitely have occurred without a side airbag, but this case is thought to be a good example of valuable deployment.

In case 2 it is less clear what effect side airbag deployment has had on thoracic injury outcome during individual case analysis, due to the crash configuration and impact pattern. The impact is narrower than in case 1 whilst the area of crush is undoubtedly in the driver's area it is more concentrated on the leg rather than the torso. The driver was 160 cm and 70 kg which would not necessarily indicate she was sitting far forward in normal driving conditions. The impact was also more clearly from behind the driver than in case 1 (4 o'clock direction of force) so the driver would not have been moved forward into the maximum intrusion zone by the impact. Bruising on the back of the driver supports this. Due to these reasons it is likely that side airbag deployment has had less of an effect than in case 1.

The two case examples given in this paper give an illustration of how changes in crash configuration, that may not be identified in overall statistical analysis, may have an effect on the influence that the deployed side airbag has on injury outcome. Obviously it is possible to separate tree/pole impacts with those involving other vehicles in overall statistical analysis, but only if case numbers allow such a breakdown. Less likely is that the exact location of intrusion and exact direction of force can be appreciated in an overall statistical analysis for side impacts.

Statistical Analysis

This paper proposed an additional evaluation of the effectiveness of side airbags in preventing thoracic injuries to passenger car occupants involved in side crashes. In-depth accident data from France, the UK and Germany has been collected and combined in a single dataset (which is rather rare and thus innovative) but the sample size remained low. Out of 2,035 side impact accident cases available in the databases, there were 435 occupants of passenger cars (built from 1998 onwards) involved in an injury accident between year 1998 and year 2004 for EES values between 20km/h and 50 km/h – the conditions where side airbags were expected to show an injury reduction effect.

The logistic regression analysis, aimed at estimating the odds ratio corresponding to the deployment of a side airbag (supposedly protecting the thorax or both the thorax and the head) versus no side airbag, was not able to conclude with a statistically significant estimation of the odds ratio. However, the estimation is positive (OR=0.83 for the reduction of AIS 2+ and AIS3+ thoracic injuries). Furthermore, case reviews in the literature suggest that side airbags should have an overall benefit for head and thorax protection.

The absence of statistical significance is assumed to be due to lack of statistical power due to a low number of cases. A significant odds ratio of 0.83 would have needed a sample size of 8,400 accident cases for $1-\alpha = 95\%$ and a statistical power of 80%.

Another possibility lies in the combination of the 3 accident databases that were used: LAB(France), CCIS (UK) and GIDAS (Germany). It is possible that the estimation of violence of impact, i.e. EES, has not been carried out the same way by different experts. Some data was also missing. On the other hand, we were not able to add more variables in the regression analysis or in the selection criteria.

Impact angles, hit obstacle, CDC deformation, location of impact were not used, because they were not systematically available in the databases. Their availability would have permitted a larger sample and the consideration of additional confounders.

Unfortunately, statistical analysis for head injuries was not possible due to the low number of accident cases with passenger cars fitted with head side airbags in the databases.

The results are nevertheless encouraging and suggest that a larger sample size should be available soon, either by combining more European databases or by waiting for the databases used here to get additional side impact cases.

This paper uses accident data from the United Kingdom Co-operative Crash Injury Study. CCIS is managed by TRL Ltd on behalf of the Department for Transport (Transport Technology and Standards Division) who fund the project with Autoliv, Ford Motor Company, Nissan Motor Europe and Toyota Motor Europe. The data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham, the Vehicle Safety Research Centre at Loughborough University, and the Vehicle & Operator Services Agency of the Department for Transport. Further information on CCIS can be found at <http://www.ukccis.org>.

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