

SIDE AIRBAG DEPLOYMENTS IN THE UK – INITIAL CASE REVIEWS

Alan Kirk and Andrew Morris

Vehicle Safety Research Centre

Loughborough University

United Kingdom

Paper No. 100

ABSTRACT

As in-vehicle safety technology becomes more prevalent, the corresponding fitment of side airbags in the United Kingdom is now more commonplace. This study adds to the body of knowledge on real world impacts by presenting initial cases of deployment from the UK, including examples where there is some suggestion that side airbag deployment may have contributed to injury outcomes.

With the introduction of new restraint devices into the vehicle fleet, manufacturers and engineers are not only eager to quantify their benefit and injury mitigation effectiveness but to also consider the performance and application in the real world. Whilst there are presently insufficient numbers of cases to fully evaluate injury benefit in side impacts, individual case evaluations can provide an initial assessment of side airbag field performance.

In this study, data from 47 crashes in which the side airbag deployed were available for analysis. Of these, 19 occupants sustained a MAIS ≥ 2 injury. Case reviews have identified 2 occupants where serious (AIS 3) thoracic injuries may have occurred through interaction with the deploying side airbag and a further case involving upper extremity fracture (AIS 3) was also thought to have been associated with side airbag deployment. In these 3 cases, crash severity and compartmental deformation were not considered to be extensive. However in the majority of cases, side airbag deployment did not cause injury to the occupant and a general overview of these cases is given.

KEYWORDS: Side Airbags, Side Impacts, Injury Severity, Head, Thorax, Restraint Injury

INTRODUCTION

Due to a large number of case data it is possible to carry out overall benefit analyses to evaluate frontal crash injury protection from European steering wheel airbags (Frampton et al, 2000, Kirk et al, 2002). However, such analyses are presently not possible for side airbags, due to small numbers of case data. However individual case reviews are possible and these allow a preliminary assessment in the first instance.

This work utilises the most recent data from the UK Co-operative Crash Injury Study (CCIS) for an initial investigation of side airbag deployments.

Where possible comparison of individual cases is made with the experimental work.

Laboratory Studies

Much laboratory work has examined the injury risk to out of position (OOP) occupants from side airbag deployment. However there are at present only limited field data that examine injury outcome in real world crashes. Recent laboratory and field study work is summarised below.

Kallieris et al (1997) observed one humerus fracture in five cadaver tests where the forearm was placed on the door rest and the (seat mounted) side airbag deployed. The study suggests that this fracture occurred due to cushion fabric failure, leading to abnormal gas distribution, a focused impact force, and brittleness of the bone. Tests were also carried out with Hybrid III dummies and the study concludes that a more biofidelic Hybrid III dummy arm is needed.

Schroeder et al (1998) examined both seat mounted and door mounted side airbag systems in static inflation and dynamic sled tests but did not find significant upper extremity injuries amongst post-mortem human subjects through interaction with the side airbag. However, they did observe bony injuries to the chest (particularly rib and sternum fractures) in the sled test series. Age of the subject was thought to be a major factor in thoracic injury outcome.

Jaffredo et al (1998) found that upper extremity forces measured on both the Eurosid-1 (with Hybrid III arms) and cadavers were lower than those required for fracture and in fact, no major injuries were observed in the four cadaver tests. However, as with other studies, upper extremity kinematics between dummy and cadaver were found to differ and no correlation could be found between forces measured on the dummy and cadaver injuries.

Tylko et al (2000) performed both static and dynamic out of position tests using child dummies to evaluate potential side airbag related injury.

Both thoracic and head side airbags were assessed. There was some suggestion that airbags could cause serious and/or fatal neck and chest injuries for out of position children. Further work (2001) suggested that properly restrained children in appropriate child seats/restraints would receive some protective benefits from side airbags.

Duma et al (2001) report upper extremity response to (seat mounted) side airbag loading using computer simulations, dummy experiments and small female cadavers. When the cadaver forearm was placed on the armrest, all six of the cadaver tests resulted in upper extremity injuries. In 4 of the tests, elbow joint surface fractures occurred whilst 2 tests resulted in comminuted mid-shaft humerus fractures (AIS 3). Wrist injuries were also found in 2 tests.

Field Studies

There are a number of limited field studies that have been reported on to date.

Langwieder et al (1998) found contusions and a sprain to the right arm of a passenger that may have developed due to side airbag contact.

Baur et al, (2000) present cases in which side airbag systems (thoracic and head) have helped to prevent serious injuries. Roselt et al. (2002) further report on 19 cases of driver side airbag deployment where detailed injury descriptions were available. No injuries were associated with side airbag deployment in either paper.

Morris et al (2000) describe a real-world case in which 84-year-old male driver was involved in a low severity side impact crash with negligible intrusion of the door structure. The side airbag (housed in the door) was found to have deployed through the door cap. The driver sustained right side rib fractures, with haemothorax and liver laceration, which were thought to have been associated with deployment of the side airbag. The age of the driver and his seating position at the time of the crash are thought to have been factors in injury outcome.

NHTSA report one serious injury related to side airbag deployment (Chidester 2001). He describes a side impact crash with subsequent deployment of a door mounted thoracic airbag which resulted in closed fractures of the 6,7 and 8th left lateral ribs with left anterior pneumothorax. Abrasion to the left lateral chest was also stated.

Dinas et al (2002) conducted an observational roadside study of vehicle occupants and their seating position relative to the side of the vehicle.

They found that a significant number of occupants were seated in positions that offered potential for injury from side airbag deployment. This was particularly found to be the case when the vehicle was turning and cornering.

METHODOLOGY

In-Depth Data

The data for this work were collected as part of the UK Co-operative Crash Injury Study (CCIS) and the analysis covers cases investigated from 1998 to 2002. The CCIS study uses in-depth retrospective procedures involving vehicle examination and hospital medical data. The study also adopts a stratified sampling system such that nearly all 'fatal' accidents, 80-90% of the 'serious' accidents (usually admission to hospital) and 20-30% of 'slight' accidents are investigated in selected regions of the UK. For a crash to be investigated, at least one of the vehicles must be less than 7 years old, towed from the scene and contain at least one injured occupant. Injury outcome is assessed using the Abbreviated Injury Scale (AAAM, 1990). As the CCIS sample is biased towards more serious injury outcomes, only inferences of relative injury risk can be made about the whole UK population as a whole. A more detailed methodology can be found in Hassan (1995). Drivers sit on the right in the UK.

Data Selection: Cases in this study were selected if a side airbag (thoracic or head) had deployed adjacent to a vehicle occupant.

RESULTS

Characteristics of the Sample

Number Of Cases: For the study 50 occupants, who were sitting adjacent to at least one deploying side airbag in 47 crashes, were available for analysis. Occupant positions are shown in Table 1.

Table 1. Occupant Position and Airbag Types

		Head airbag present (cant rail mounted)	
		No	Yes
Driver	Door	6	8
	Seat	27	1
Front Seat Passenger	Door	2	1
	Seat	4	-
Rear Passenger	Door	-	1
	Seat	-	-

Table 2 shows seat belt use in the crashes investigated. Whilst the seat belt is not thought to play a significant role in injury prevention in perpendicular side impacts, it is more important in oblique angled crashes.

Table 2. Seat Belt Use

Seatbelt Use	n=50	
Belted	41	82%
Unbelted	2	4%
Unknown	7	14%

Although it is not always possible to be wholly accurate about the impacts that vehicles have sustained, (particularly if they involve multiple events), classification of a lateral element of the crash has been applied in all cases. These are shown in Table 3. A lateral impact has been defined as a 2 to 4 o'clock impact (60 to 120 collision angle) to the right and 8 to 10 o'clock (-120 to -60 collision angle) to the left.

Table 3. Lateral Element to Impact

Lateral	No roll	Roll After impact	Roll Without impact	Roll Between impacts	Total
No	16	1	4	1	22
Yes	26	2	-	-	28
Total	42	3	4	1	50

More detailed information is shown in the individual case reviews but the overall analysis shows that 32% of the side airbag deployments in this study occurred in crashes with no lateral element in the crash. Table 3 also shows that some crashes are rollovers, with 6 of the 22 'non lateral' crashes involving an element of roll.

Collision partners are shown in Table 4. It is interesting to note the high numbers of wide roadside objects involved, the majority of which were found to be trees and poles.

Table 4. Collision Partner

Collision Partner	Lateral	
	No	Yes
Car / car-derivative	4	10
MPV / LGV	1	-
HGV / PSV	2	5
Pole / narrow object <41cm	1	1
Wide roadside object >41cm	10	12
No impact	4	0
Total	22	28

INJURY ANALYSIS

Whole Body Injury Severity

The distribution of the maximum AIS (MAIS) of the sample is given in Table 5. As can be seen from the table, the majority of cases involved 'no' or 'minor' injury.

Table 5. MAIS Distribution

MAIS	n=50	
0 – No injury	3	6%
1 – Minor	25	50%
2 – Moderate	8	16%
3 – Serious	7	14%
4 – Severe	2	4%
5 – Critical	1	2%
6 – Maximum	1	2%
Unknown	3	6%

Case Review Methodology

Each case with side airbag deployment was individually assessed to determine as far as possible cases where,

- Deployment had no influence on occupant injuries;
- Crash severity was too high to expect injury mitigation;
- Deployment prevented injury; and
- There was a possible causal relationship between the injuries to the adjacent occupant and deploying side airbag.

As the case studies presented here are amongst the first real-world evaluations of side airbag deployment, comments are also directed towards the issues of deployment thresholds (including direction of impact).

In the total sample, there were many different combinations of crash types and injury outcomes. The sample was therefore split into a number of broad categories based on crash type and injury outcome.

These were as follows;

- (a) No expected benefit of airbag deployment due to crash type or low crash severity;
- (b) No expected benefit of airbag deployment due to high crash severity;
- (c) Perceived injury prevention benefit through airbag deployment in side impacts;
- (d) Unexpected injury with airbag deployment; and

- (e) Benefit difficult to assess due to crash complexity.

These are discussed in turn and illustrative examples are included.

(a) No expected benefit of airbag deployment due to crash type or low crash severity

This category included a number of cases in which the crash type was such that the occupant was not likely to contact the side of the vehicle due to the likely human kinematic response to the impact. These cases included non-struck side crashes, primarily frontal crashes, non-horizontal impacts, rollover crashes and sideswipe crashes. 16 out of 50 occupants were judged to have been involved in such crashes.

A further 7 occupants were involved in crashes where it is likely that interaction with the side airbag had occurred but it is unlikely that in a low severity crash it has been of benefit to serious injury prevention.

Case Example 1

The vehicle lost control on a bend, leaving the road and becoming airborne, colliding with a tree, a non-horizontal impact. The driver's injuries were loss of consciousness (AIS 2), multiple fractures of the right hand (AIS 2) and right femur fracture (AIS 3), from crushing to the legs under the fascia region. The deployment of side airbag did not prevent or cause injury, since the non-horizontal impact was not in the area of the side airbag. The driver was trapped by the collapse of the fascia onto the legs. Both head and door mounted thoracic side airbags deployed.



Case Example 1



Case Example 1

Case Example 2

The vehicle was struck on the left side by another car whilst turning right with an impact delta-V calculated in the region of 29km/h. The 30 year old female belted driver on the non-struck side received only slight bruising and lacerations to the face (AIS 1). As the driver was moving away from her door it is not likely that deployment of the side seat airbag prevented any injuries to the driver. Both frontal and left side airbags also deployed. There was no front seat passenger.



Case Example 2

Case Example 3

The vehicle was struck on the left side, forward of the passenger compartment by another vehicle at a crossroads. The Equivalent Barrier Speed in the case vehicle was in the region of 13km/h but with no intrusion of the passenger door. The seat-mounted passenger thoracic side airbag was the only airbag deployment in the vehicle. The 28-year old belted female front seat passenger (weight 61kg, height 1.65metres) sustained neck strain and bruising to the right knee and left shin (all AIS 1). Neck strain is reported for the driver.



Case Example 3



Case Example 3



Case Example 4



Case Example 4

(b) No expected benefit of airbag deployment due to high crash severity

This category included a number of high-speed crash events in which the side airbag would be expected to offer little benefit to the adjacent occupant due to the severity of the crash. An example is shown below.

In total 4 out of the 50 occupants in the sample were involved in such crashes.

Case Example 4

The driver of this vehicle lost control and the vehicle sustained two subsequent impacts with a tree, the main impact being to the left side of the vehicle. The impact delta-V was calculated to be in the region of 67km/h and there was substantial crush across the width of the vehicle with major residual intrusion (116cm) of the passenger compartment. The belted driver of the vehicle, a 48-year old male (weight 87kg, height 1.88metres) sustained catastrophic injuries to the chest (MAIS 6, ISS=75) together with serious head and abdominal injuries.

(c) Perceived injury prevention benefit through airbag deployment in side impacts

In this category, some injury mitigation benefit of the deploying airbag was determined. Such assessment was based on consensus of available information about each crash. Examples are shown below.

In total, 9 out of 50 occupants were involved in crashes whereby the injury outcome was determined to have been less severe than might have been otherwise expected.

Case Example 5

In this example, the case vehicle emerged from a junction and was struck in the driver's side by a truck. The Equivalent Barrier Speed in the case vehicle was in the region of 22km/h and there was some 32cm of crush to the driver door. The seat-mounted thoracic side airbag was the only airbag deployment in the vehicle. The 28-year old belted

female driver (height and weight unknown) sustained neck strain and some general bruising (MAIS=1) but no other reported injury.



Case Example 5



Case Example 5

Case Example 6

The vehicle sustained a side impact to the driver's side with a brick wall, although from the intrusion profile it is evident that a brick column in the wall was involved. The Equivalent Barrier Speed was calculated to be in the region of 18km/h with intrusion of 29cm to the driver's door.

No AIS \geq 2 injuries were sustained by either occupant, even though the front seat passenger was not belted. The driver's thoracic side airbag was the only airbag in the vehicle to deploy and is likely to have helped prevent serious injuries to the 25 year old male belted driver.



Case Example 6



Case Example 6

(d) Unexpected injury with airbag deployment

In this category, unexpected injury outcomes were observed. Of the 50 occupants in the sample, there were 3 cases where it is considered that the airbag contributed (at least in part) to injury outcomes. These are shown below.

Case Example 7

The driver of this case vehicle lost control of the vehicle on a left hand bend and the vehicle sustained a subsequent impact with the central reservation barrier. Residual damage occurred to the nearside of the vehicle with 23cm of crush depth to the front nearside region (but no residual intrusion in the passenger compartment). The front passenger's seat-mounted side airbag deployed in the crash. The Equivalent Barrier Speed was calculated to be in the region of 29km/h.

The driver was not injured. However, the belted passenger, a 25 year-old female (weight 55kg, height 1.63metres) sustained fractured left 7th, 8th and 9th ribs with haemo/pneumothorax (AIS=3), a pulmonary contusion to the left lung (AIS=3) and a splenic tear (AIS=2, overall ISS=14).



Case Example 7

Case Example 8

In this case, the vehicle left the road for no apparent reason and subsequently rolled (1/2 turn) down an embankment before coming to rest on its roof.

There was little by way of residual crush to the vehicle and a maximum residual roof intrusion of some 4cm.

The driver of the vehicle was a belted 28-year old female (weight 59kg, height 1.68metres). The seat-mounted thoracic airbag deployed during the crash. The driver sustained fractures of the 6th, 7th and 8th right-side ribs with haemo-pneumothorax (AIS=3).



Case Example 8



Case Example 8

Case Example 9

The driver of this vehicle lost control on a left-hand bend and collided with the side of a building. There was little overall damage to the passenger compartment and calculation of crash severity was not possible due to the nature and type of impact. The direction of force was predominantly 'frontal', however the main area of damage was to the right side of the vehicle.

An unbelted male front seat passenger was not injured in the crash. The unbelted driver of the vehicle, a 21-year old male (height and weight unknown) who was sat adjacent to a deployed seat-mounted head-thorax side airbag sustained numerous minor injuries (AIS=1) as well as a comminuted mid-shaft fracture of the right humerus with distal fragment with a resulting adduction of 40-45 degrees and proximal shift of 2-3cms (AIS=3). This injury was deemed to have occurred through interaction with the deploying side airbag.

In this case the side airbag pierced through the door cap (the door interior at the base of the window).



Case Example 9



Case Example 9

(e) Benefit difficult to assess due to crash complexity

Of the 50 cases in the sample, there were 11 cases in which an assessment of benefit or dis-benefit could not be determined due to complexity of the event. Such cases usually involved complicated crash conditions with multiple series of events in which it was difficult to fully determine the precise point of airbag deployment.

Case Example 10

The vehicle in this crash was travelling on a dual carriageway when the driver lost control and the vehicle struck the central reservation barrier. The vehicle then rotated across the carriageway and struck a concrete wall on an emerging slip road.

The vehicle was equipped with thoracic side airbags in the rear doors and a full-length curtain head side airbag. There was deployment of all side-airbags on the driver's side only.

The belted front seat occupants (driver, male 24 years; front seat passenger, female 23 years) sustained only slight bruising and the rear left-side occupant was not injured.

The crash severity calculations were not made due to the nature of the damage but the vehicle sustained a maximum damage crush of 35cm from the first impact (to the right front of the vehicle) and 25cm (to the right rear of the vehicle) from the second impact. However there was negligible intrusion (maximum of 3cm) in the passenger compartment. The right rear passenger, a 50-year old female (height and weight unknown) sustained severe injuries to the head (sub-dural haematoma and small intracranial haemorrhage, both AIS 4) and fracture of the pelvis (both superior and inferior pubic rami on the right and distribution of sacro-iliac joint on the left side, AIS 2). The right arm was also bruised (AIS 1).

The deployment of the side airbag did not prevent AIS 4 head injury to the rear passenger but the source of the injury could not be fully determined. Further confounding factors include the complexity of occupant kinematics in the crash and determination of the point of deployment in the crash (i.e. did deployment occur during the first or second impact).



Case Example 10



Case Example 10

DISCUSSION

Any restraint system carries a certain risk of injury from the system itself. It is therefore vital to know the balance of that risk compared to the overall benefits of the system.

To set the benefits of side airbags into context a much larger dataset is required. However, the authors feel that it is important to present these initial findings to identify initial benefits and potential problems with side airbag technology. When looking at the bigger picture in overall benefit analyses using mass data, it is usually very difficult to identify specific details of individual crashes as have been presented here.

It would be interesting if further work in this area investigated cases where side airbag deployment would be expected but did not occur, this was outside of the scope of this present study.

A number of cases in this study have been identified where benefits of side airbag deployment are apparent. However, it is almost certain that the overall benefits of side airbags are larger than reported in this study since the sample includes crashes involving injury to at least one vehicle occupant. Therefore cases involving no reported injury are not sampled and not subjected to in-depth review in the UK CCIS study. In the future there may be the possibility of investigation using no injury occupants in injury cars from the CCIS study or cases from the UK 'On the Spot' study, which includes damage only vehicles. It is likely that case numbers would be small though.

As expected the published information on side impact deployment cases is scarce although it is interesting to compare the cases here with the few found in the literature and the findings of laboratory work.

A review of the published literature reveals that upper extremity injuries can be induced through interaction with deploying side airbags using experimental procedures but that the laboratory conditions necessary to induce fracture were considered to be not often met in real-world situations. Furthermore, in certain situations where fractures were induced experimentally, the condition of the subjects used was such that the possibility of fracture was increased due to changes in bone mineral content or the presence of other underlying physiological degeneration. Whilst the results indicate a low risk of upper extremity injury, on balance, some risk still exists. For example, in two of the six cadaver tests conducted by Duma et al (2001), comminuted mid-shaft humerus fractures occurred. The data presented in this paper contain

one anecdotal case to support this injury outcome (case example 9). It is worth considering that the risk of upper extremity injuries through interaction with side airbags would not be detected in regulatory compliance testing using crash-test dummies since no dummy currently exists with instrumentation capable of identifying such a risk.

A lack of correlation between cadaver and dummy tests is reported in some of the papers, which may have implications in the modelling of side airbag deployments, especially regarding deployment induced injury.

In two of the cases investigated where injury was suspected due to airbag interaction, the injury outcome was very similar. In case example 7, the main injury outcome involved fractures to 7th, 8th and 9th ribs together with haemo-pneumothorax (AIS=3). In case example 8, the main injury outcome involved fractures to 6th, 7th and 8th ribs together with haemo-pneumothorax (AIS=3). Both these cases involve similar injury outcomes to a case investigated by Morris et al (2000) in which an elderly driver sustained multiple rib fractures together with haemo-pneumothorax and also to a case reported by Chidester (2001) where 6th, 7th and 8th rib fractures were observed. Whilst the anecdotal nature of such cases is acknowledged, the injury outcomes suggest a need for future monitoring and evaluation through real-world crash research. It should also be noted that similar injury levels have been observed and induced experimentally in static inflation conditions, particularly with door mounted side airbag systems (Schroeder et al 1998).

In addition to cases of unexpected thoracic injury, one case is reported in which unexpected severe head injury occurred to a rear seat passenger (case example 10). It should be noted that the crash involved a complex series of events and therefore a full assessment cannot be made.

In this study, some side airbags appear to have deployed in crash circumstances where benefit of such systems would not be expected, notably impacts involving a largely frontal direction of impact force. However, there may be benefit of deployment in such crashes particularly if there is a subsequent rotation of the vehicle following initial impact. Determining such benefit would be difficult in practice though, especially the timing of deployment.

In a few cases crash severity was very severe and beyond the protection capabilities of most if not all safety systems. Such cases illustrate that in certain types of crashes it is difficult to provide any real

benefit to vehicle occupants given current design constraints.

Unlike the range of frontal steering wheel airbags, which are essentially similar in design and deploy in a similar manner, side airbags differ in shape, size and location in relation to the occupant's body. To aid this type of work in future in-depth studies, investigators should strive to ensure that the information recorded is as complete as possible.

Limitations of the Study

In this study, there were no identified cases of children adjacent to a deploying side airbag in this initial sample. It would be worthwhile in the future for any such cases to be compared with the laboratory work carried out by Tylko (2000, 2001).

It is difficult to determine using retrospective crash investigation techniques at what point in the impact sequence that the side airbag has deployed. It is also difficult to determine the position of the occupant in relation to the deploying airbag during the crash. This is especially the case in multiple impacts.

As the CCIS study is essentially an injury-based study with a sample biased towards serious and fatal injury severity crashes, it is inevitable that some 'success' stories are missed.

CONCLUSIONS

This paper may pose more questions than it answers, as it is a first look at side airbag deployment. However, the authors feel that by consideration of individual cases including aspects such as impact type, airbag deployment, intrusion and occupant injury, these cases offer a first indication to restraint engineers on deployment circumstances in real world accidents.

Main Points for consideration:

- Side airbag deployments are preventing injuries in the real world.
- Side airbag deployment is 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.
- As expected cases have been found in this initial sample in which the crash severity exceeded the protection capabilities of most modern safety systems.
- Some cases are presented in which the side airbag deployment may have caused serious injury where it would not otherwise have been expected. Future consideration should be given to possible injury mechanisms and further studies of side airbag deployments are essential.

- As case numbers increase, statistical analysis should be used to establish any difference in injury patterns between side airbag equipped and non-equipped vehicles.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the funding of the initial stages of this work by the Department for Transport (DfT) in the United Kingdom.

This paper uses accident data from the United Kingdom Co-operative Crash Injury Study (CCIS).

CCIS is funded by the Department for Transport (Vehicle Standards and Engineering Division), Autoliv, Ford Motor Company, Toyota Motor Europe, Nissan, Visteon, Daimler-Chrysler and LAB. CCIS is operated by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre of Loughborough University; the Vehicle Inspectorate Executive Agency of the DfT and TRL Limited.

Further information on CCIS can be found at <http://www.ukccis.com/>

REFERENCES

Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale 1990 Revision, 1990.

Baur, P., Lange, W., Messner, G. Rauscher, S. Pieske, O. Comparison of Real World Side Impact / Rollover Collisions With and Without Thorax Airbag / Head Protection System: A First Field Experience Study. 44th AAAM, Chicago, 2000.

Chidester, A., Roston T., Air Bag Crash Investigations. National Highway Traffic Safety Administration. Proceedings of ESV, Amsterdam, The Netherlands, 2001. Paper number 246.

Chidester, A. Real World Experience of Side Impact Air Bags in the Special Crash Investigations (October 25th, 2001) NHTSA website.

Dinas, A., Fildes, B. Observations of Seating Position of Front Seat Occupants Relative to the Side of the Vehicle. 46th AAAM, Tempe, 2002.

Duma, S.M., Boggess, B.M., Crandall, J.R., Hurwitz, S.R., Seki, K., Aoki, T. Analysis of Upper Extremity Response Under Side Airbag Loading. Proceedings of ESV, Amsterdam, The Netherlands, 2001. Paper number 195.

Frampton, R., Welsh, R., Kirk, A., Fay, P. and Sferco, R., Effectiveness of Airbag Restraints in

Frontal Crashes-What European Field Studies Tell Us. Proceedings of IRCOBI Conference on the Biomechanics of Impact, Montpellier, France, 2000, pp 425-438.

Hassan, A.M., Hill, J.R., Parkin, S., Mackay, G.M. Secondary Safety Developments: Some Applications of Field Data. Autotech 1995, Birmingham, U.K. London: IMechE, 1995.

Jaffredo, A.S., Potier, P., Robin, S., Le Coz, J.Y., Lassau, J.P. Upper Extremity Interaction with Side Impact Airbag. Proceedings of IRCOBI Conference on the Biomechanics of Impact, Goteburg, Sweden, 1998, pp 485-496.

Kallieris D., Rizetti A., Mattern R., Jost S., Priemer P., Unger M.: Response and Vulnerability of the Upper Arm Through Side Airbag Deployment. SAE paper No 973323, Proceedings: 41st Stapp Car Crash Conference, Florida, 1997, page 101-110

Kirk, A., Frampton, R., and Thomas, P., An evaluation of airbag benefits/disbenefits in european vehicles – A combined statistical and case study approach. Proceedings of IRCOBI Conference on the Biomechanics of Injury, Munich, Germany, September 2002.

Langweider, K., Hummel, T. A., Anselm, D. The Effects of Airbags on Injuries and Costs. Proceedings of ESV, Windsor, Canada, 1998. Paper number 98-S1-W-27.

Morris, A., Begbie, J., Fildes, B., Barnes, J., Claessens, M. ANCIS-In-Depth Crash Injury Research in Australia. Road Safety Researcher's Conference, Brisbane, Australia, 2000.

Roselt, T., Langweider, K., Hummel, T., Koster, H.W. Injury Patterns of Front Seat Occupants in Frontal Car Collisions with Airbags. Effectivity and Optimisation Potential of Airbags. IRCOBI, September 2002, Munich, Germany.

Schroeder, G., Tschaschke, U., Scheunert, D., Schutz, J., Zobel, R. Are Sidebags Dangerous in Certain Seating Positions? Proceedings of IRCOBI Conference on the Biomechanics of Impact, Goteburg, Sweden, 1998, pp 477-483.

Tylko, S., Dalmotas, D. Assessment of Injury Risk to Children from Side Airbags. Stapp Car Crash Journal 44, November, 2000. pp 13-24.

Tylko, S., Dalmotas, D. Side Airbags: Evaluating the Benefits and Risks for Restrained Children. Proceedings of ESV, Amsterdam, The Netherlands, 2001. Paper number 420.