REVIEW

Injuries associated with airbag deployment

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Motor vehicle crashes are a leading cause of morbidity and mortality in the United Kingdom. Airbags drastically reduce both morbidity and mortality from crashes, but with the increased use of airbags there has been a corresponding increase in the number of injuries attributable to these devices. This review discusses the history and mechanism of action of airbags, along with the spectrum of injuries seen as a result of their deployment, and future advances that may be of benefit in increasing motor vehicle safety.

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Injury prevention is an increasingly important component of healthcare policy in many developed countries, especially where limited resources are an important constraint. It is a stated aim of the United Kingdom government, for example, to reduce trauma deaths among children and young adults by 20% (from 1996 levels) by 2010.[1] The commonest cause of such deaths in the UK is motor vehicle crashes (MVC), and the same is true of the United States of America.[2] In the UK in 1996, 250 000 MVC victims attended hospital and 3000 of them died.[1]

In both the UK and USA, the number of car users who have been killed or seriously injured has fallen over the past 30 years despite huge increases in the volume of traffic (R Cuerden, *et al,* 63rd Road safety conference, 1998). There have been many national programmes over the years to effect this reduction: useful strategies have included rigorous enforcement of speed limits, compulsory seat belt wearing and, more recently, the introduction of airbags into vehicles. Although correctly fitted three point seat belts have been shown to be safer than airbags,[4] there is no doubt that airbags in themselves reduce deaths.[3] If both devices are used together, further reductions in mortality are to be expected.

The first airbag was fitted to a car in the USA in the 1950s. In the mid-1980s Passive Safety Federal Legislation was passed with a resultant increase in airbag use. In 1995, over 70% of new USA cars had airbags installed, and it has been mandatory in law to provide driver and passenger airbags in all new cars in the USA since 1998. At present, there is no law governing the use of airbags in the UK (although there are rules for their storage and fitment).

In 1983, 14% of USA drivers used seat belts; more modern estimates[5] put the figure at up to 60%. Although this figure is improving, USA airbags have had to be designed to protect both the belted and unbelted occupant. To achieve this, airbags inflate rapidly (50 ms) under high pressure to a volume of 70 litres. In contrast, UK (and Western European) fitted airbags are only designed to protect a belted occupant and inflate to 30 litres within the same time. This is in part attributable to seat belt use in the UK and Europe, which is estimated at 88%–91% (dependent on sex and age, R Cuerden, *et al,* IRCOBI Conference, 2001).

The first driver's side airbag was introduced in the UK in the late 1980s, but such devices only became widely available when Ford began to fit them in 1992. More recently, passenger side airbags have become more commonplace. While airbags have obvious benefits, there has been a corresponding increase in the number of injuries seen as a result of airbag deployment.

The first case report of an airbag associated fatality in the UK was published in 2000.[6] In the USA, where airbags are larger and more powerful and seat belt law varies from state to state, airbag related deaths and injuries are more common.

METHOD

We undertook a review of the literature to determine the spectrum of injuries resulting from airbag fitment and deployment.

Medline and Embase were searched using the WebSpirs interface. All relevant articles were retrieved and reviewed; other articles were found from references in these papers. Where more than one case of an identical injury has been reported, only the first case has been included.

MECHANISM OF ACTION

During a motor vehicle crash, four collisions may occur[2]:

First Between the vehicle and the other object

Second Between the unrestrained occupant and the interior of the vehicle

Third Between the occupants organs and the enclosing body wall or cavity (skull, chest wall, etc)

Fourth Between the occupant and loose objects in the vehicle.

Deceleration forces are dependent on the deforming ability of the vehicle. Newer vehicles are produced with the evidence from crash research studies in mind, and are designed to deform extensively on impact. This is intended to result in a reduction in the forces applied to the occupants.

When an unrestrained person strikes the interior of the vehicle, the stopping distance for an unbelted person is determined by the "give" in the car interior with which they impact. A belted occupant, on the other hand, decelerates over a larger distance determined by the "give" in the seatbelt.

Airbags are intended to impact on the second collision, and are based on a simple concept: on frontal impact of the vehicle, a deflated balloon stored in the steering wheel or fascia is rapidly inflated under high pressure to protect the occupant. On the driver's side, this protection is from steering wheel impact. Other airbags provide protection against striking the dashboard or side panels.

Airbag inflation occurs via a deceleration sensor that triggers a small charge (producing temperature variation from ambient, to 700°C, and back again in less than 0.1 seconds). Once inflated, vents in the material of the bag permit immediate deflation. If the deceleration sensor is set too high, lower energy crashes that should result in deployment will be missed; similarly, if it is too sensitive the airbag will deploy in minor shunts.

Furthermore, the timing of the airbag must be adjusted so that it is inflated to its maximum as the occupant impacts onto it. If it inflates too soon, it will be deflated by the time the occupant strikes the wheel; too late, and the occupant will be in the inflation zone when the bag fires.

Studies to date have almost exclusively concentrated on frontal impacts. In part, this is because they constitute 50%–65% of all crashes (R Cuerden, *et al,* IRCOBI Conference, 2001), but also because impact of the occupant from a frontal collision will be toward the forward structures. Lateral impacts generally produce sideways motion (side airbags are increasingly common), and rear impact protection is afforded through seat back load deflection characteristics (alongside head restraints).

EFFECTS OF AIRBAG USE

The mandatory wearing of seat belts in the UK has contributed to a dramatic reduction in the number of deaths and serious injuries on our roads. However, seatbelts have their limitations—most notably in allowing the head to strike the steering wheel (R Cuerden, *et al,* IRCOBI Conference, 2001).

The use of airbags is known to save lives[2 7] and reduce the incidence of serious injury in non-fatal MVCs (for example they have been shown to reduce the risk of severe facial injury,[8] and produce a one third reduction in serious injuries to the head (J Lenard, *et al,* 16th International technical conference on the enhanced safety of vehicles, Windsor, Canada, 1998). Airbags are, however, designed to be used in conjunction with a properly fitted three point seatbelt, and the absence of such a restraint can permit otherwise preventable injuries.

Injuries have been described resulting from all stages of airbag deployment, and all components of the system: from non-deployment, spontaneous deployment, the pyrotechnic used, expansion of the bag, contact with the bag, and over-rapid deflation.[9–11]

An all encompassing review of data from the ongoing UK Co-operative Crash Injury Study (collecting data on all serious motor vehicle crashes since 1983) (R Cuerden, *et al,* IRCOBI Conference, 2001) found that, for seat belted drivers in frontal impact crashes, the presence of a deployed airbag led to:

- No difference in maximum abbreviated injury score (MAIS) 2 or greater (2+) injury for similar crashes.
- 42% reduction in MAIS 2+ cranium injury.
- 70% reduction in MAIS 2+ facial injury.
- No difference in MAIS 2+ chest injury.
- Significantly more MAIS 2+ injuries to the arms and right shoulder.

SPECTRUM OF INJURY

There is convincing evidence from both sides of the Atlantic that airbags provide excellent protection against serious injury. However, there is an increasing amount of data on injuries directly attributable to these devices.

In a retrospective review of United States National Highway Traffic Safety Administration (NHTSA) data from 1980 to 1994,[12] there were 618 injuries, of which 42% affected the face, 33% the upper limb, and 9.6% the chest. The most important finding, however, was that 96% of all injuries were classified as minor. This suggested that although airbags doubtless do cause injury, such injuries must be viewed in the context of the more severe injuries that they prevent.

Frampton (R Frampton, *et al*, IRCOBI conference, Montpellier, France, 2000) compared the rate of abbreviated injury score (AIS) 2 or greater injury in UK and European airbag equipped cars against non-equipped, and found a statistically significant reduction in these serious injuries (24% *v* 29%, $p=0.02$). Of note, he also found that the pattern of AIS 2+ injury appears to be changed by the presence of airbags, with a greater tendency for upper limb injury, and less head and neck injuries. For minor injuries (AIS 1), there were still more arm injuries in airbag fitted cars, but less head, neck, and leg injuries. These data were similar to that produced by Lenard (J Lenard, *et al,* 16th International technical conference on the enhanced safety of vehicles).

Head and neck

There have been multiple reports of head and neck injuries related to airbags, mostly (but not uniquely) from the USA. Injuries include facial trauma,[8] temporomandibular joint injury,[13] decapitation,[14] and cervical spine fractures.[15 16] In addition to bony neck injuries soft tissue injuries are also seen with both types of system, including damage to the vasculature.[17–19] The eye seems to be particularly vulnerable to injury, especially if spectacles are worn[20]: injuries include orbital fractures,[21] retinal detachment,[22] and lens rupture.[23] The chemicals involved in inflating the bag have been implicated in eye injury,[24] as have the cover components.[25] Front seated children are also at risk of eye injury.[26] Eye injuries are more commonly reported in the USA.

Despite the many case reports and series discussing head and neck injuries arising from airbag deployment, it is important to remember that the head and neck are at very significant risk in a frontal impact, from contact with the steering wheel (especially if a seat belt is worn). Frampton provides good evidence (R Frampton, *et al*, IRCOBI conference) that UK and European airbags are effective at protecting against serious head injury: in this study the rate of AIS 2 or greater head injury was 32% lower in the presence of airbags ($p<0.05$); the reduction in AIS 2+ facial injuries was 55% ($p<0.05$). Comparing airbag with no airbag showed a trend in these head injured patients to have more brain injuries and less skull fractures. This non-significant trend may represent airbags providing greater protection to the bony elements of the skull than the brain tissue.

Torso

Multiple case reports can be found of injuries to the chest and abdomen. Once again, these injuries occur more commonly but not uniquely with the larger US systems. Chest injuries include rib fractures,[27 28] bilateral pneumothorax,[29] aortic transection,[30 31] heart valve injury[32] and cardiac rupture.[33] There are reports of overt abdominal injury,[34] and occult injuries.[35] Additionally, thoraco-lumbar spine injuries are not uncommon.[36]

Frampton (R Frampton, *et al*, IRCOBI conference) looked at the incidence of severe (AIS2+) injury to the chest and abdomen in crashes with and without airbags: there was a non-significant increase in chest injuries in the presence of UK and European airbags, and no difference in the rate of abdominal injuries. Cuerden's review of the CCIS data confirmed these findings (R Cuerden, *et al,* IRCOBI Conference, 2001).

Upper limb

A whole range of injuries have been reported on both sides of the Atlantic,[37–39] with the shoulder and forearm being the commonest sites in both airbag and no airbag crashes (R Frampton, *et al*, IRCOBI conference). The clavicle is the commonest site of AIS 2+ injury. Frampton (R Frampton, *et al*, IRCOBI conference) and Cuerden (R Cuerden, *et al,* IRCOBI conference) both demonstrated a significant increase in minor and more serious injuries to the upper limb after airbag deployment. Most of these were fractures or dislocations (95%). Some studies have suggested that the trend is actually the other way, with minor injuries being commonplace.[40]

Interestingly, although the difference in AIS 2+ injuries was statistically significant between airbag and no airbag crashes in Frampton's work (R Frampton, *et al*, IRCOBI conference), the majority affected the outside shoulder (84% and 95%), and were felt to represent the forces applied by the shoulder strap of the seat belt.

Lower limb

Common sense would dictate that airbags would have no overall effect on the incidence and severity of leg injuries, and this seems to be borne out in the literature. One paper described several cases of leg injury from crashes in airbag equipped cars, but made no attempt to ascribe these injuries to airbag deployment.[41] There seems to be a protective effect of airbags on minor leg injuries, but no effect on more severe injury rates (R Frampton, *et al*, IRCOBI conference).

Other injuries

A range of other "miscellaneous" injuries have been associated with deployment of both US and the smaller UK/European systems, including acoustic damage,[42] premature rupture of the membranes in pregnancy,[43] and burns.[44–46]

Some groups have differing risks, particularly those of short stature,[47] and some congenital abnormalities[48] and this should be borne in mind when assessing crash victims for injury.

Injuries in children

Evidence from the United States suggests that passenger airbags are associated with an increased risk of death in children.[49–51] Passenger airbags in vehicles have been associated with fatal and non-fatal injuries in children of all ages. Two scenarios are thought to contribute to these injuries: infants in rear facing child seats strapped into the passenger seat may sustain severe head and neck injuries caused by the deployment of the bag and forward facing children who are unbelted (or improperly belted) can have their heads in the deployment area of the bag, once again causing severe head injuries. Graham[50] presented data from the US that suggest that passenger airbags are not only associated with cases of child fatalities, but also that the protective effects of the bags in terms of lives saved is outweighed by the lives lost. However, for each of the child lives lost by passenger airbags in the USA, 5–10 adults are saved[52]: this figure is 75 lives saved to one life lost for driver's side airbags.[53]

In the USA, about one third of children travelling in cars do so in the front seat; this figure is less than 15% in Europe (this may be explained by legislation that has only recently been repealed, prohibiting children from travelling in front seats in several European countries).[50] The rear seats are known to be safer than front seats for passengers of any age,[54] and there is now evidence from the US that the presence of a passenger airbag is enough to make parents seat their children in the rear, to protect them from airbag associated injury.[55] Thinking may be changing: this can only have a beneficial effect on child injuries.

Deaths

Many of the injuries reported above have been fatal. The only case report of a fatality in the UK was as recently as 2000.[6] With the larger airbags in the United States, deaths are much commoner.[51 56]

The aim in the USA must be to reduce the number of deaths through modifications in design, and the UK based system would seem better. However, with the large number of injuries attributed to airbags, the search for improvements in design must continue.

ALTERNATIVE RESTRAINT SYSTEMS

Head restraints

Front seat head restraints have been mandatory in the US since 1969 (Federal Motor Vehicle Safety Standard 202) and, although law in the UK does not yet require them, they are subject to European Safety Regulations. They are designed primarily to reduce the incidence of neck injuries after front or rear impacts. However, evidence suggests that they are ineffective at providing this protection, either because they are poorly designed or not correctly positioned by the seat occupant (I Olsson I, *et al,* IRCOBI conference, Bron, France, 1990). These devices should be positioned so that they are centred on the centre of gravity of the head, and at a minimum horizontal distance from the head. As few as 10% of drivers comply with this (D C Viano, *et al*, 39th American Automobile Association (AAA) conference, Chicago, USA, 1995).

Improvements in the design of head restraints could lead to a marked reduction in "whiplash" type injuries: "smart" systems that take account of biomechanical differences in car occupants and adjust accordingly are under investigation (M Mackay, *et al*, Joint AAA–IRCOBI special session, Lyon, France, 1994).

Seat belt advances

Seat belts have already been identified as providing a high level of protection,[3] but their limitations are recognised (M Mackay, *et al,* International conference on real world crash injury research, 1997). Five areas of limitation are described:

- head and face contact with the steering wheel
- intrusion of frontal structures
- rear loading
- misuse of the seat belt
- injuries from the seat belt itself.

Some of these problems can be tackled in other ways, such as the provision of steering wheel mounted airbags to reduce injuries from steering wheel contact, or the use of education programmes to ensure correct use of seat belts. Advances in seat belt design will be required to have a further impact on injuries related to their use.

Proposed changes (M Mackay, *et al,* International symposium on real world crash injury research, 1997) include: variable pretensioning force (related to impact speed and occupant characteristics); discretionary web locks (the amount of belt put under tension is varied according to occupant characteristics), and variable sitting position sensors (to feed information about the occupant back to seat belts and airbags).

Smart airbags

These devices are still in the trial phase, but are looking promising for the future. Different car occupants would be sensed, and a number of alterations automatically made to the airbag. Potential developments include adjustment of the triggering force, gas volume and inflation rate. Advanced sensing and control systems will be necessary for these to become a reality.

CONCLUSION

Airbags have been fitted into cars for nearly 50 years, although they have only been commonplace in the UK for one decade. During this time there have been numerous reports of injuries directly attributable to airbags, with some calls for them to be removed or deactivated. While accepting that these injuries occur, most (up to 96%) are comparatively minor. Most occur with the larger system used in the US, although UK airbags have been associated with a wide range of injuries.

There is no doubting the overwhelming evidence that airbags are effective at saving lives and preventing serious injury, particularly if used with a well fitted three point seat belt, and any injury attributable to their use must be seen in light of this knowledge.

Future advances in airbag technology will help to reduce injuries caused by these devices, but will need to be implemented in conjunction with advances in other restraint and sensing systems to be most effective.

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Contributors

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REFERENCES

1 **Department of Health**. *Our healthier nation*. London: The Stationery Office, 1998.
2 **US Department of Transportation Highway Traffic Safety Administration**. *Traffic safety facts*. Washington: US Dept of Transportation, 1997.
3 **Barry S**, Ginpil S, O'Neill TJ. The effectiveness of air bags. *Accid Anal Prev* 1999;**31**:781–7.
4 **Zador PI**, Ciccone MA. Automobile driver fatalities in frontal impacts: airbags compared with manual belts. *Am J Public Health* 1993;**83**:661–6.
5 **Peterson TD**, Jolly BT, Runge JW, *et al*. Motor Vehicle Safety: Current concepts and challenges for emergency physicians. *Ann Emerg Med* 1999;**34**:384–93.
6 **Cunningham K**, Brown TD, Gradwell E, *et al*. Airbag associated fatal head injury: case report and review of the literature. *J Accid Emerg Med* 2000;**17**:139–42.
7 **Department of Transport**. NHTSA Presidential Initiative for increasing seat belt use nationwide–recommendations from the secretary of transportation. Washington: Department of Transport, 1997.
8 **Murphy RX**, Birmingham KL, Okunski WJ, *et al*. The influence of airbag and restraining devices on the patterns of facial trauma in motor vehicle collisions. *Plast Reconstr Surg* 2000;**105**:516–20.
9 **Adams SL**, Petri RW. Injury with spontaneous deployment of an automobile air bag. *Acad Emerg Med* 1996;**3**:179–80.
10 **Baruchin AM**, Jakim I, Rosenberg L, *et al*. On burn injuries related to airbag deployment. *Burns* 1999;**25**:49–52.
11 **Smock WS**, Nichols GR. Airbag module cover injuries. *J Trauma*. 1995;**38**:489–93.
12 **Antosai RE**, Partridge RA, Virk AS. Air bag safety. *Ann Emerg Med* 1995;**25**:794–8.
13 **Levy Y**, Hasson O, Zeltser R, *et al*. Temporo-mandibular joint derangement after air bag deployment: report of two cases. *J Oral Maxillofac Surg* 1998;**56**:1000–3.
14 **Huff GF**, Bagwell SP, Bachmann D. Airbag injuries in infants and children: a case report and review of the literature. *Pediatrics* 1998;**102**: electronic
15 **Hart RA**, Mayberry JC, Herzberg AM. Acute cervical spinal cord injury secondary to air bag deployment without proper use of lap or shoulder harnesses. *J Spinal Disord* 2000;**13**:36–8.
16 **Bailey H**, Perez N, Blank-Reid C, *et al*. Atlanto-occipital dislocation: an unusual lethal airbag injury. *J Emerg Med* 2000;**18**:215–19.
17 **Duncan MA**, Dowd N, Rawluk D, *et al*. Traumatic bilateral internal carotid artery dissection following airbag deployment in a patient with fibromuscular dysplasia. *Br J Anaesth* 2000;**85**:476–8.
18 **Epperly NA**, Still JT, Law E, *et al*. Supraglottic and subglottic airway injury due to deployment and rupture of an automobile airbag. *Am Surg* 1997;**63**:979–81.
19 **Perdikis G**, Schmitt T, Chait D, *et al*. Blunt laryngeal fracture: another airbag injury. *J Trauma* 2000;**48**:544–6.
20 **Duma SM**, Kress TA, Porta DJ, *et al*. Airbag induced eye injuries: a report of 25 cases. *J Trauma* 1996;**41**:114–19.
21 **Cacciatori M**, Bell RW, Habib NE. Blow-out fracture of the orbit associated with inflation of an airbag: a case report. *Br J Oral Maxillofac Surg* 1997;**35**:241–2.
22 **Ruiz-Moreno JM**. Air bag-associated retinal tear. *Eur J Ophthalmol* 1998;**8**:52–3.
23 **Zabriskie NA**, Hwang IP, Ramsey JF, *et al*. Anterior lens capsule rupture caused by air bag trauma. *Am J Ophthalmol* 1997;**123**:832–3.
24 **Smally AJ**, Binzer A, Dolin S, *et al*. Alkaline chemical keratitis: eye injury from airbags. *Ann Emerg Med* 1992;**21**:1400–2.
25 **Duma SM**, Crandall JR. Eye injuries from airbags with seamless module covers. *J Trauma* 2000;**48**:786–9.
26 **Lueder GT**. Air bag-associated ocular trauma in children. *Ophthalmology* 2000;**107**:1472–5.
27 **Daniels RJ**, Fulcher RA. An unusual cause of rib fracture following a road traffic accident. *J Accid Emerg Med* 1997;**14**:113–14.
28 **Stoneham MD**. Bilateral first rib fractures associated with driver's air bag inflation: case report and implications for surgery. *Eur J Emerg Med* 1995;**2**:60–2.
29 **Morgenstern K**, Talucci R, Kaufman MS, *et al*. Bilateral pneumothorax following air bag deployment. *Chest* 1998;**114**:624–6.
30 **DeGuzman BJ**, Morgan AS, Pharr WF. Aortic transection following airbag deployment. *NEJM* 1997;**337**:573–4.
31 **Dunn JA**, Williams MG. Occult ascending aortic rupture in the presence of an air bag. *Ann Thorac Surg* 1996;**62**:577–8.
32 **Sharma OP**, Mousett XR. Review of tricuspid valve injury after airbag deployment: presentation of a case and discussion of mechanism of injury. *J Trauma* 2000;**48**:152–6.
33 **Lancaster GI**, DeFrance JH, Borruso HH. Airbag associated rupture of the right atrium. *NEJM* 1983;**328**:358.
34 **Smith DP**, Klein FA. Renal injury in a child with airbag deployment. *J Trauma* 1997; **42**:341–2.
35 **Augenstein JS**, Digges KH, Lombardo LV, *et al*. Occult abdominal injuries to airbag-protected crash victims: a challenge to trauma systems. *J Trauma* 1995;**38**:502–8.
36 **Ball ST**, Vaccaro AR, Albert TJ, *at al*. Injuries of the thoracolumbar spine associated with restraint use in head-on motor vehicle accidents. *J Spinal Disord* 2000;**13**:297–304.
37 **Richter M**, Otte D, Jahanyar K, *et al*. Upper extremity fractures in restrained front-seat occupants. *J Trauma* 2000;**48**:907–12.
38 **Lundy DW**, Lourie GM. Two open forearm fractures after airbag deployment during low speed accidents. *Clin Orthop* 1998;**351**:191–5.
39 **Marco F**, Garcia-Lopez A, Leon C, *et al*. Bilateral Smith fracture of the radius caused by airbag deployment. *J Trauma* 1996;**40**:663–4.
40 **Huelke DF**, Moore JL, Compton TW, *et al*. Upper extremity injuries related to airbag deployments. *J Trauma* 1995;**38**:482–8.
41 **Burgess AR**, Dischinger PC, O'Quinn TD, *et al*. Lower extremity injuries in drivers of airbag-equipped automobiles: clinical and crash reconstruction correlations. *J Trauma* 1995;**38**:509–16.
42 **Buckley G**, Setchfield N, Frampton R. Two case reports of possible noise trauma after inflation of airbags in low speed car crashes. *BMJ* 1995;**18**:499–500.
43 **Gimovsky ML**, Nunez G, Beck P. Fetal heart rate monitoring casebook. Airbag-associated rupture of membranes: evaluation of trauma in pregnancy. *J Perinatol* 2000;**20**:270–3.
44 **Heimbach D**. Full-thickness burn to the hand from an automobile airbag. *J Burn Care Rehabil* 2000;**21**:288–9.
45 **Baruchin AM**, Jakim I, Rosenberg L, *et al*. On burn injuries related to airbag deployment. *Burns* 1999;25:49–52.
46 **Hallock GG**. Mechanisms of burn injury secondary to airbag deployment. *Ann Plast Surg* 1997;**39**:111–13.
47 **Roberts D**, Pexa C, Clarkowski B, *et al*. Fatal laryngeal injury in an achondroplastic dwarf secondary to airbag deployment. *Pediatr Emerg Care* 1999;**15**:260–1.
48 **Duncan MA**, Dowd N, Rawluk D, *et al*. Traumatic bilateral internal carotid artery dissection following airbag deployment in a patient with fibromuscular dysplasia. *Br J Anaesth* 2000;**85**:476–8.
49 **Braver ER**, Whitfield R, Ferguson SA. *Risk of death among child passengers in front and rear seating positions*. Arlington, US: Insurance institute for highway safety, 1997.
50 **Graham JD**, Goldie SJ, Segui-Gomez M, *et al*. Reducing risks to children in vehicles with passenger airbags. *Pediatrics* 1998;**102**:electronic.
51 **Huff GF**, Bagwell SP, Bachmann D. Airbag injuries in infants and children: a case report and review of the literature. *Pediatrics* 1998;**102**:electronic.
52 **Braver ER**, Ferguson SA, Greene MA, *et al*. Reductions in deaths in frontal crashes among right front passengers in vehicles equipped with passenger airbags. *JAMA* 1997;**278**:1437–9.
53 **NHTSA Federal motor vehicle safety standards: occupant crash position**. *Federal Register* 1997;**62**:812.
54 **Evans L**, Frick M. Seating position in cars and fatality risk. *Am J Public Health* 1988;**78**:1256.
55 **Wittenberg E**, Nelson TF, Graham JD. The effect of passenger airbags on child seating behaviour in motor vehicles. *Pediatrics* 1999;**104**:1247–50.
56 **Lund AK**, Ferguson SA. Driver fatalities in 1985–1993 cars with airbags. *J Trauma* 1995;**38**:469–75.