

Pneumothorax, without chest wall fracture, following airbag deployment

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Abstract

Air bags are an automatic crash protection system. They have been shown to reduce mortality from motor vehicle accidents by 31% following direct head-on impacts, by 19% following any frontal impact and by 11% overall. Despite obvious benefits there has been a corresponding increase in the number of injuries resulting from their deployment. We describe a case of a pneumothorax in the absence of chest wall pathology associated with airbag deployment, in a belted driver. There has been one previous description of pneumothorax associated with airbag deployment, in an unbelted driver.

Introduction

Motor vehicle accidents are the commonest preventable cause of death in the young in the United Kingdom (UK) and United States (USA).^{1,2} In 1996, 250,000 crash victims attended hospital of which 3000 died.¹ In the UK the aim is to reduce trauma deaths in children and young adults by 20% (from 1996 levels) by 2010.¹ However, despite huge increases in traffic over the past 30 years, the numbers of deaths and serious injuries have fallen.³ There have been many national programmes to account for this including enforcement of speed limits, compulsory seat belt wearing and more recently air bags.

Correctly fitted three point seat belts have been shown to be safer than airbags.⁴ There is no doubt that airbags reduce deaths alone.⁵ If both devices are used together then further reductions in morbidity and mortality can be anticipated.

In 1983 14% of US drivers used seat belts. More modern estimates are roughly 60%, although this figure is improving⁶ despite seat-belt law varying from state to state. As a result of these low figures, US airbags, which have been mandatory in new vehicles since 1998, have had to be designed to protect both the belted and unbelted occupant. To achieve this airbags inflate rapidly (50 msec) 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 timeframe. Here the compliance with seatbelt use is 88-91% depending on age and gender.⁷ Though fitted as standard in many vehicles, airbags are still not mandatory in new cars, as they are in the US. In addition to frontal deployed devices, side impact airbags are now increasingly used.

Whilst they provide obvious benefits, there has been a corresponding increase in the number of injuries seen as a result of airbag deployment. These include acoustic damage/hearing loss,⁸ burns,⁹ eye perforation by a tobacco pipe,¹⁰ rib fracture,¹¹ sternal fracture,¹² ocular injury,¹³ facial injury¹⁴ and vascular injury.¹⁵ There has been one previous description of pneumothorax associated with airbag deployment,¹⁶ in an unbelted driver.

In a retrospective review of US National Highway Traffic Safety Administration (NHTSA) data from 1980 to 1994,¹⁷ there were 618 injuries directly attributable to airbag deployment. Of these injuries, 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. Injuries must therefore be viewed in the context of the more severe or potentially severe injuries that they prevent. In 2003 the NHTSA confirmed 77 adult drivers and 10 adult passengers had been killed by air bags.¹⁸ This compares with only one case reported in the UK.⁶

Case Report

A fit and well 23-year old male was involved in a head-on collision with another vehicle. He was a non smoker of normal physic. His vehicle was travelling at approximately 50 mph but the combined speed was unknown. The air bag deployed on impact. The driver was assessed at the scene by the emergency services and no injuries were apparent, so admission to hospital was not thought necessary. He did however report feeling 'winded' from the time of the impact. At home he continued with discomfort on inspiration and subsequently attended the A&E department later the same day.

Clinical examination and chest x-ray revealed a right-sided pneumothorax, but no fracture was seen (Figure 1). The pneumothorax was treated with an intercostal drain. The patient had no other injuries. After two weeks the drain was removed, at which time a small air pocket was still visible, this did not expand, so he was discharged. There were no further problems in the follow-up period and further radiographs quickly returned to normal.

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Discussion

During a vehicle crash four collisions can occur:

1. the vehicle collision with another object;
2. the impact of the occupants with the vehicle interior;
3. the collision between organs and hard surfaces;
4. collisions between loose objects (including unrestrained passengers) and the occupants.

Seat belt usage, airbag deployment and vehicle design all control the effective stopping distance and hence deceleration, and possibly outcome. Air bags inflate from the centre of the steering wheel when crash sensors detect the rapid deceleration associated with a frontal impact. This ignites an electrical charge (momentary rise in temperature to 700°C) on a pyrotechnic device (sodium azide) producing gases (nitrogen 96%, carbon dioxide 3% and particulates) within a folded bag (dusted with talcum powder).

In a 35 miles per hour (mph) frontal barrier test (accounting for sensing and intrinsic system actuation), an air bag must inflate completely in approximately 30 milliseconds (ms).¹⁹ If one assumes the chest-instrument panel distance of a typical car is 45 cm, the average velocity of the air bag's leading edge is about 15 metres per second (34 mph) with a maximum velocity as high as 90 m/s (200 mph).²⁰ This can lead to extremely high peak internal pressures in the bag during the break out phase.

Normally the airbag gases overcome the

resistance of the inner and outer containers allowing the bag to break out of the module. Gas then continues to fill the bag outside the module. Air bag inflation can generate a sound pressure level of 150-170 dB in under 100 ms, with an inflation speed of 100-200 mph.²¹ Negligible vertical forces occur because the driver should only impact with a fully inflated bag; the restraining force therefore evenly distributed over the contact area. However should the occupant obstruct the deployment, markedly high punch out forces can be generated, which can induce injury to the body part in direct contact with the cover module. This phase is of relevance with passengers who deviate from the *normal* body habitus or incorrectly position themselves in the vehicle. A short stature person is likely to be closer to the steering wheel hence within the deployment zone.²² Even if fully restrained they are at risk of *late deployment* which is defined as the airbag's punch out phase not occurring until the occupants are so far forward they are near the airbag cover.²³ The earlier in the inflation sequence that contact occurs, then the greater the impacts force.

Short or unrestrained occupants can also be subjected to upward/ vertical extension forces resulting in cervical and facial injury. The post punch-out phase of deployment, called the plateau phase can also cause injuries remote to the initial site of bag contact. This is of particular relevance in the US with the larger airbags and unbelted occupants.

Injuries have been described resulting from all stages of airbag deployment and all components of the system. These include non-deployment, spontaneous deployment, the pyrotechnic used, expansion of the bag, contact with the bag, and over-rapid deflation.^{9,24,25} A pattern of mostly minor injuries secondary to air bag deployment in correctly restrained occupants has emerged.²⁶ There is also accumulating evidence that on rare occasions there is a potential for more serious injury. Although facial injuries are the most common, irrespective of whether the airbag deploys or not, the pattern of injuries are very characteristic. The pressure wave effect also has been shown to cause barotrauma resulting in hearing loss,⁸ ocular trauma including perforation of the globe, aortic dissection, premature rupture of membranes in pregnancy and C1/2 fracture dislocation.^{27,28}

The pressure/velocity magnitudes depend of the size of car, number of occupants, ventilation openings, and the size, number and inflation rate of airbags.²² In the US there are regulations defining the minimum safe distance from the sternum to the steering wheel of ten inches and that if this distance is not possible then to obtain a manual cut-off button for their airbag.²⁹ One study from Boston has shown that this distance is hard for people to esti-

mate.³⁰ It can also be hazardous if the occupant is out of position or there is any other obstruction to bag inflation.

The possible lung parenchyma injury mechanisms, responsible for the injury sustained here are either concussion or compression. Concussion occurs with high velocity impacts at low displacements of the chest wall resulting in shear stress that exceeds the elastic properties of the lung. In the younger occupant, the more elastic and compliant chest wall is believed to allow the transmission of kinetic energy more efficiently to the underlying lung parenchyma.

Compression occurs by two possible scenarios in low velocity impacts with high displacements of the chest wall. It can occur either by compression of the chest in the form of a valsalva mechanism (compression against a closed glottis) or external compression by an external force. Secondly relative compression can occur by direct jet insufflation with an open glottis squeezing the lung tissue against the relatively rigid chest wall that cannot expand quickly enough to accommodate the change in force, creating a bursting effect.³¹ Anaesthetists are acutely aware of this scenario to avoid setting mechanical ventilatory support inflation pressures too high.

Frampton *et al.*³² compared the frequency of abbreviated injury score (AIS) 2 or greater in UK and European airbag equipped cars against non-equipped cars. They found a statistically significant reduction in these serious injuries (24% vs. 29% $P=0.02$) in cars equipped with airbags. It was also noted that the pattern of injuries changed by the presence of airbags. There was a greater tendency for upper limb injuries, with 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.

Regarding the incidence of severe (AIS 2+) injury to the chest and abdomen in crashes with and with out 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.³²

Cuerden's review of the UK Co-operative Crash Injury Study (CCIS) data confirmed these findings, collating data since 1983 on all serious road accidents.⁷ For seat belted drivers in frontal impact crashes the presence of deployed air bag led to:

1. No difference in maximum abbreviated injury score (MAIS) 2 or greater (2+) injury for similar crashes.
2. 42% reduction in MAIS 2+ cranium injury
3. 70% reduction in MAIS 2+ facial injury
4. No reduction in MAIS 2+ chest injury
5. Significantly more MAIS 2+ injuries to the arms and right shoulder.

Both of these studies have shown the increased risk of chest injury associated with



Figure 1. Chest X-ray showing a right sided apical pneumothorax with a chest drain in-situ. There is no evidence of chest wall fracture.

airbag deployment.

Smart airbags are in the trial phase and can alter the inflation characteristics of the airbag, according to the occupant's weight and height, and the triggering force. These may have some impact in the future in reducing direct and inadvertent injuries.

There is no doubt that airbags are effective at saving lives and preventing serious injury especially when used with a well fitted three point seat belt. Any injury attributable to their use must be seen in light of this knowledge. Although US designs differ from European airbags they do still carry the potential for serious injury. Whereas the pneumothorax reported in the US was in an unbelted driver with a 70 L airbag our case shows that even when belted a smaller 30 L deployment carries the potential for significant injury.

On balance, we feel that that our case may have sustained open high pressure insufflation as he had no associated injuries. He also had little awareness of the impact to brace himself. He did mobilise immediately from the vehicle so there was little chance of prolonged exposure. He was not aware of any bag failure and had no risk factors for pneumothorax.

We feel that this case demonstrates the importance of a thorough assessment of all occupants in vehicles involved in accidents where airbag deployment has occurred. The presence of occult injuries directly related to airbag deployment needs to be specifically assessed and these risks reinforced to all involved in the care of motor vehicle accident victims.

We hope this ensures future drivers and emergency crews appreciate that airbags, although good at damage limitation, do have specific risks. They are not a safety device to compensate for bad driving and it is critical to read the vehicle manual or speak to the car dealer if there are concerns regarding body posture, habitus or seat position. Reports arising from the introduction of new safety systems have to be balanced against the research

clearly showing airbags have saved lives and reduced injury. Also clearly no safety system can be expected to protect against the consequences of every possible impact situation.

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