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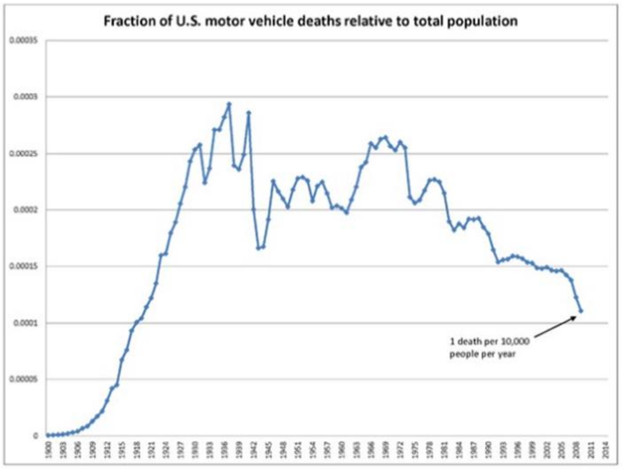
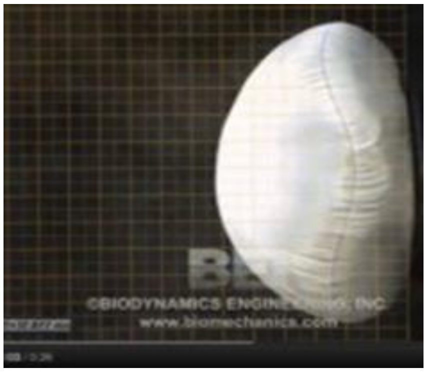
White Papers in Audiology

Hearing Loss, Tinnitus and Air Bag Deployment

A review of automobile safety shows one of the worst years in the US for automobile accidents was 1936, when the death rate was almost 3 in every 10,000 people. At that time, auto safety was not considered a priority and safety equipment for vehicles was nonexistent. Since the 1950s, safety has become a priority in automobile design and the statistics are substantially better. Although deaths were reduced to some degree in the 1950s and 60s, automobile deaths did not get under 2 in every 10,000 until the 1980s. Since that time, the [incidence of deaths](#) from automobile accidents, at least in the US, have been reduced to a bit over 1 in every 10,000 people. While this is an admirable reduction of deaths due to traffic accidents, significant credit must go to automobile safety equipment, automobile design, building materials, seat belts and, especially, air bags. These days automobiles are literally crammed with airbags which are deployed as the vehicle hits something from virtually any angle, reducing injury to the occupants. Vehicles in many countries are [tested for their road](#) worthiness and to evaluate the danger to the occupants as they are crashed from various angles.





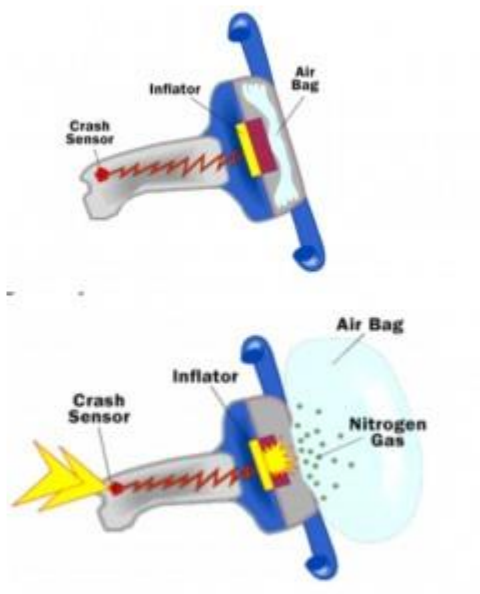
How do Air Bags Work?

Basically, the air bags work in conjunction with the seat belts to keep the driver from hitting things within the vehicle upon impact. Click on the picture of the air bag to for a demonstration of how it deploys. The next video demonstrates what happens to the occupants of the vehicle when these bags deploy, click of the picture of the car to see how the bags protect us in a crash.

Now, click on the picture of the Blue car as it crashes. First, the video presents the car crash itself, then moves into how the air bags deploy and how it saves the driver. The driver seems to be well protected by the air bag system within the vehicle.

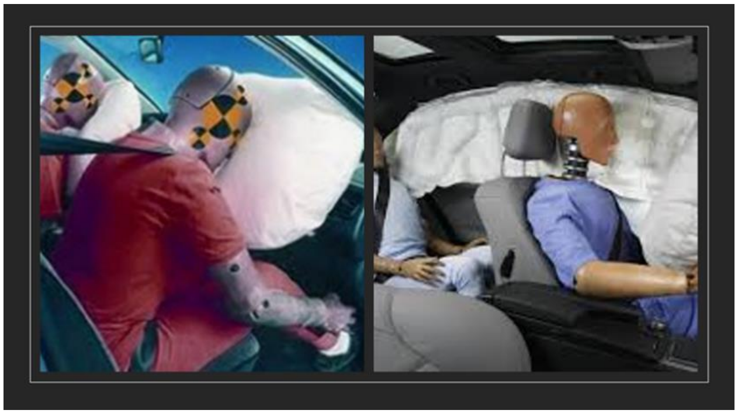
How do Air Bags Work?

Air bags respond to a sensor in the front of the vehicle that, when actuated, causes the bag to inflate and protects the occupant. Some of these bags are more sophisticated than others as this technology is constantly being updated and modified. Brain (2018), describes an airbag restraint system as consisting of four major components working together to slow a passenger's forward motion as evenly as possible in a fraction of a second. He further describes the parts that make up this restraint system as: the airbag, the air bag cover, the inflation system and the sensor. A defect in any of these parts could result in an unwarranted injury to the occupant. The airbag itself is made of thin, nylon fabric that is folded into its storage site, usually located in the steering wheel, dashboard, seat or door. The bag is covered with a dust that consists of cornstarch, chalk, or talcum powder, which provides lubrication during deployment. The bag material is designed to have a degree of porosity. This allows the bag to moderately deflate after inflation and provide the proper cushioning for the occupant. To protect and hide the air bag system when not in use, a cover over the system is provided. The heart of the airbag system is the inflator. The inflation system design requires the combination of the skills of rocket propellant engineers along with those of auto mechanical engineers. These systems have changed substantially over the years, but currently the initiator (sometimes called an igniter or squib) receives an electrical signal from the sensor/electronic module located in strategic points on the vehicle, and then it ignites a solid propellant, which burns extremely rapidly to create a large volume of gas to inflate the bag. Ohki, Ishikawa & Tahara (2012) state that the deployment of air bags has been reported to inflict damage on the face, neck, upper chest, and abdomen. Specific areas for these injuries included, eyes, facial nerve, cervical spine, temporomandibular joint, upper airway, lungs, and heart. While air bag deployment has rarely been reported to cause otologic injuries there were injuries caused by air bags, particularly those manufactured by the now bankrupt Japanese company Takata. By now, late 2018, most Takata systems have been recalled and are not part of current vehicle manufacturing worldwide.



What About Hearing Loss and Tinnitus After Airbag Deployment?

The amount of noise associated with airbag deployment from a car accident varies with the vehicle and the the type, size and location of the airbag. Deployment of a driver’s side front airbag will generate mean peak sound pressure levels of approximately 160 dB (decibels). A passenger side front airbag will generate mean peak sound pressure level of 168 dB, while dual airbag deployments create a mean peak sound pressure level of 170 dB. When you compare these intensities with the level of of sound in decibels that can cause hearing loss, the problem becomes evident. Studies have shown that the pain threshold from noise is about 140 dB and that a single exposure to sound pressure of this level can cause permanent, severe hearing loss.

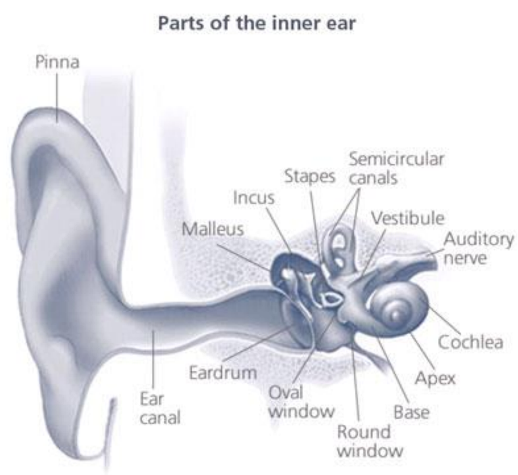


The most recent development of side airbags now standard in most vehicles has only enhanced this problem. The deployment of a side airbag generates a mean peak sound air pressure of 178 dB. That is more than 20% higher than the level necessary to cause permanent severe hearing loss. Add in the fact that the side air bag deploys closer to the ear and the danger becomes escalated. Over the years, sensorineural hearing loss due to air bag deployment was thought to be rare, but audiologists have known for many years that 140 dB is the threshold of pain and these intensities are dangerous and can cause hearing loss.

A researcher, Price (2007), presented data at the National Hearing Conservation Association's 32nd Annual Conference that predicted 17% of occupants exposed to deployed airbags in American cars will suffer from permanent hearing loss and/or tinnitus. His analysis was conducted using the Auditory Hazard Assessment Algorithm for the Human (AHAAH) model, which utilizes anatomical components of the ear's structure to predict hearing loss due to exposure to intense sounds above 130 dB. The AHAA model is used by the United States Army and has been shown to predict hearing loss accurately in 95% of the cases in which human ears have been exposed. Previously, hearing scientists thought rolled-up windows presented more danger to hearing as they allow for higher pressure to be created inside the cabin. Price's research, however, concludes that having car windows rolled up when airbags are deployed is less hazardous to the ear than rolled-down windows. This is because the higher pressure generated in the closed cabin prevents greater damage to the ear. The pressure causes a displacement in the middle ear that stiffens the stapes, a small bone outside the middle ear. This stiffening limits the transmission of energy to the inner ear, where hearing damage takes place. In airbag experiments where the cabin is completely sealed, and pressure is even higher, hearing damage is reduced even further. This stiffening of the ossicular chain has been known to in the otologic literature as the *Acoustic Reflex.* Due to current literature, the acoustic reflex has now been implemented by one auto manufacturer to generate a noise eliciting this reflex prior to an accident in their cars beginning in 2016

What Actually Happens to the Auditory Mechanism?

In the past few years, I have been involved in several cases where the deployment of an air bag has created or exacerbated a hearing loss and/or tinnitus ("ringing in the ear"). Davis and Rafaie (2000) state that excessive noise exposure is known to be one of the major factors that affect the auditory system at various levels, causing hearing loss and tinnitus. Noise may be identified by its intensity, frequency spectrum and duration. It may be continuous, intermittent, fluctuating impulsive or explosive. After review of a wealth of literature, they summarize that noise exposure can lead to hair cell damage, especially the outer hair cells through metabolic exhaustion or mechanical detachment from the basilar membrane and that biochemical changes in the cochlea and damage to the auditory nerve and central auditory system are also implicated. Kushi (1999) presents that theoretical predictions based on a mathematical model of auditory hazard, and confirmed by animal and human experiments, demonstrate it is likely that more than 90% of individuals will be at risk for hearing or balance disorders when current airbags are deployed under conditions involving open windows, unanticipated deployments, and heads turned so that an ear faces the airbag. Of course, these head angles are not under control during an accident and/or air bag deployment. Hickling et al (2002) presented data that summarizes then air bag injuries of 66 people that presented with otologic injuries subsequent to automobile accidents where the air bags deployed.



Data from Hickling et al (2002), Patients with Otologic Symptoms resulting from Airbag Deployment

Male	26
Female	40
Average Age	51.5 years
Age Range	4 to 81 years
Tinnitus (permanent)	52
Unilateral Hearing Loss	47
Vertigo	13
Recruitment	6
Perforation of the Tympanic Membrane	6*
Perilymph Fistula	1
Benign Paroxysmal Positional Vertigo	7

*4 of the 6 required surgical repairs.

Under best case scenarios, the risk ranges from less than 1% to a few percent of individuals who will be affected. Morris and Borja (1998) found that ear injury may show up as more hearing loss or tinnitus as either condition is commonly associated with inner ear damage and usually effects frequencies above the speech frequency range. Thus, air bag deployment may not only cause hearing deficits but may also result in the onset or exacerbation of tinnitus. While Price (2007) states that this may happen in only about 17% of those occupants where air bags deploy, these situations may be minimal or a devastating lifestyle disruption for those involved. Why these injuries happen to some individuals and not to others is still unclear but there are some logical deductions that could be made as to the reasons for symptom increases due to this type of an exposure.

- Exposure to an impulse noise of 160-178 dB can cause significant otologic injury to the inner ear and other structures. This creates huge otologic risks.

- Otologic injuries reported to be induced by air bag deployment include tympanic membrane perforation, conductive hearing loss, tinnitus, disequilibrium, and sensorineural hearing loss (McFeeley et al, 1999; Yaremchuk & Dobie, 2001).

- These injuries will occur about 17% of the time depending upon the occupant's placement in the vehicle, and their head position relative to the noise source at the time of the airbag deployment.

Some of these studies have been out in the literature for quite some time and new vehicles with different deployment methods, made from newer materials will likely create less difficulty with the actual deployment. Until the noise levels can be reduced for these deployments, the risk of otologic injury from air bag deployment will still be significant.

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