

How Have Changes in Air Bag Designs Affected Frontal Crash Mortality?

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PURPOSE: To determine whether front air bag changes have affected occupant protection, frontal crash mortality rates were compared among front outboard occupants in vehicles having certified-advanced air bags (latest generation of air bags) or sled-certified air bags with and without advanced features.

METHODS: Poisson marginal structural models were used to calculate standardized mortality rate ratios (MRRs) for front occupants per registered vehicle.

RESULTS: Vehicle age-corrected mortality rates were lower for drivers of vehicles having sled-certified air bags with advanced features than for drivers having sled-certified air bags without advanced features (MRR = 0.88; 95% confidence interval [CI]: 0.81–0.95), including unbelted men and drivers younger than 60. The mortality rate was higher, though not statistically significant, for drivers having certified-advanced air bags compared with sled-certified air bags with advanced features (vehicle age-corrected MRR = 1.13; 95% CI: 0.97–1.32) and significantly higher for belted drivers (MRR = 1.21; 95% CI: 1.04–1.39).

CONCLUSIONS: Advanced air bag features appeared protective for some occupants. However, increased mortality rates among belted drivers of vehicles having certified-advanced air bags relative to those having sled-certified air bags with advanced features suggest that further study is needed to identify any potential problems with requirements for certification.

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INTRODUCTION

Deaths in frontal crashes are reduced by front air bags (1–8); however, front air bags caused fatal or serious injuries in some low-speed crashes when introduced (1, 4, 9–12). The occupants most vulnerable to air bag-induced deaths were infants in rear-facing child seats, unrestrained children, and adults of short stature sitting too close to deploying air bags. As of Jan. 1, 2009, 296 deaths were attributed to front air bags, including 191 children, 92 drivers, and 13 adult passengers; an estimated 28,244 lives had been saved by them (13).

The National Highway Traffic Safety Administration (NHTSA) required that crash safety performance be certified for the first generation (pre-1998 models) of air bags with 30-mph (48 km/h) head-on, full-overlap rigid-barrier tests with both belted and unbelted 50th percentile male dummies in driver and right-front passenger positions. Then federal requirements for frontal crash performance were changed to reduce air bag-induced deaths (14). The next generation of air bags, hereafter referred to as sled-certified air bags, were first manufactured during model

year 1998, when NHTSA gave automobile manufacturers the option of certifying frontal crash performance for 50th percentile unbelted male dummies with 30-mph sled tests (11). In sled tests, a whole or partial vehicle is attached to a moving platform that simulates crash accelerations. The permissible sled tests had a longer deceleration during the crash than rigid-barrier tests, enabling air bags to inflate with 20% to 35% less energy (depowering) (11, 14, 15).

In 2001, NHTSA promulgated a requirement that automakers phase in advanced air bags, referred to as certified-advanced air bags, to improve protection of belted and out-of-position occupants (15). The major differences between recent and prior requirements were the wider variety of tests (full-overlap head-on, offset frontal, out-of-position scenarios) and larger span of occupant sizes. In addition to 50th percentile males, dummies representing 5th percentile adult females (belted and unbelted) and 1-, 3-, and 6-year-old children (out of position) are tested. These tests essentially require that certified-advanced systems distinguish between adult and child passengers and tailor (or suppress) deployments to occupant size, belt status, position, and crash severity. When an infant or small child is in the front seat or a small woman moves close to an air bag, these systems may either suppress deployment or deploy the air bag such that the likelihood of injury is low. Consequently, certified-advanced systems have sensors that measure crash severity, detect rear-facing child seats, and identify occupant seat belt status, weight, and proximity to

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Selected Abbreviations and Acronyms

NHTSA = National Highway Traffic Safety Administration
HLDI = Highway Loss Data Institute
ESC = electronic stability control
MMR = mortality rate ratio
CI = confidence interval
SMR = standardized mortality ratio

the air bag and thus determine whether air bags should be suppressed or deployed, and, if deployed, with what force. Typically, variable force deployment is achieved by staging deployment in phases. Certified-advanced air bags generally deploy at lower crash velocity changes for unbelted occupants.

The 2001 rule specified a 25-mph rigid-barrier frontal and offset-frontal crash test for unbelted 50th percentile male dummies. The 25-mph rigid-barrier test typically results in shorter deceleration time and higher crash forces than the 30-mph sled test, despite the lower speed; it is equivalent to two passenger vehicles (same size/weight) colliding head-on at 25 mph, representing a severe automotive impact. The rule was controversial, with some safety organizations advocating a 30-mph rigid-barrier test because they feared a 25-mph test would reduce protection for large occupants, particularly unbelted men. NHTSA (6) also thought the rule might result in more deaths among unbelted adults. Some safety organizations sued NHTSA, but the court upheld the agency. By model year 2007, all passenger vehicles were required to have certified-advanced air bags. The rule also specified a 35-mph rigid-barrier test for belted 50th percentile male dummies by model year 2010, an increase from the 30-mph test mandated by model year 2007.

Some automakers added variable output inflators and other advanced features to sled-certified air bags prior to qualifying for certification as advanced (about 46% of 1998–2005 make/models)*,† (16). Of make/models having sled-certified air bags with advanced features, dual-stage inflators were the most common feature (74%), followed by sensors that detected belt status (55%), seat position (26%), and occupant size and weight (10%). For some make/models, sled-certified air bags with advanced features closely resemble certified-advanced air bags.

*Braver ER, Scerbo M, Kufera JA, Alexander MT, Volpini K, Lloyd JP. Database from survey of automotive manufacturers conducted by University of Maryland School of Medicine (unpublished); 2008.

†National Highway Traffic Safety Administration. Safety equipment list for NASS/CDS and CIREN investigators (unpublished). Washington (DC): US Department of Transportation; 2007.

Sled-certified air bags reduce air bag-induced deaths among front-seated child passengers and do not appear to

have compromised overall protection of adults in frontal crashes (7, 14, 16, 17–24). However, research suggested that unrestrained drivers might be at higher risk of death or serious non-fatal chest injuries in vehicles with sled-certified air bags (14, 24, 25, 26).

Air bag designs have evolved to minimize the risk of air bag–induced deaths and injuries and to maximize their protectiveness, but it is not known whether advanced designs are working as intended. This study aimed to determine whether frontal crash mortality was lower among drivers and right-front passengers in vehicles having sled-certified air bags with advanced features compared with those having sled-certified air bags without such features. Another purpose was to assess the effects of the requirements for certification as having an advanced air bag (newest generation of air bag designs) by comparing frontal crash mortality rates for drivers and right-front passengers in vehicles having certified-advanced air bags with those having sled-certified air bags with advanced features.

METHODS

Driver and adult right-front passenger mortality rates were calculated as deaths per registered passenger vehicle for certified-advanced air bags, sled-certified air bags without advanced features, and sled-certified air bags with some advanced features. Among drivers, additional analyses examined effects of air bag design changes by age, gender, and belt use. Child right-front passenger mortality rates also were studied.

Data Sources

The following data sources were used for model years 1998–2006 during calendar years 2004–2007: Fatality Analysis Reporting System for deaths; R. L. Polk for vehicle registrations; and Highway Loss Data Institute (HLDI) for age and gender distributions of insured drivers by make/model, model year, and calendar year. HLDI also provided data on standard electronic stability control (ESC). Additional data on air bag generation, advanced air bag features, and seat belt pretensioners and load limiters came from NHTSA† (27) and an earlier survey of automobile manufacturers* (16). All certified-advanced air bags had advanced features. Sled-certified air bags were dichotomized as either having some advanced features or no advanced features. Few advanced features were present unless a dual-stage inflator also was present.

Study Groups

Each make/model had to have existed prior to receiving a certified-advanced air bag. Occupants of cars, pickups,

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