Traffic Injury Prevention, 11:178–187, 2010

ISSN: 1538-9588 print / 1538-957X online
DOI: 10.1080/15389580903473973

Front Air Bag Nondeployments in Frontal Crashes Fatal to Drivers or Right-Front Passengers

ELISA R. BRAVER,[1] ANNE T. McCARTT,[1] CHRISTOPHER P. SHERWOOD,[1]
DAVID S. ZUBY,[1] LAURA BLANAR,[1] and MARGE SCERBO[2]

[1]Insurance Institute for Highway Safety, Arlington, Virginia
[2]National Study Center for Trauma and EMS, University of Maryland, Baltimore, Maryland

Objective: *Public concern has arisen about the reliability of front air bags because Fatality Analysis Reporting System (FARS) data indicate many nondeployed air bags in fatal frontal crashes. However, the accuracy of air bag deployment, the variable in question, is uncertain. This study aimed to provide more certain estimates of nondeployment incidence in fatal frontal crashes.*

Methods: *Fatally injured passenger vehicle drivers and right-front passengers in frontal crashes were identified in two U.S. databases for calendar years 1998–2006 and model years 1994–2006: FARS, a census of police-reported fatal crashes on public roads, and National Automotive Sampling System/Crashworthiness Data System (NASS/CDS), a probability sample of tow-away crashes. NASS/CDS contains subsets of fatal crashes in FARS and collects detailed data using crash investigators. Front air bag deployment coding for front-seat occupant fatalities was compared in FARS and NASS/CDS, and case reviews were conducted.*

Results: *Among FARS frontal deaths with available deployment status (N = 43,169), front air bags were coded as not deployed for 18 percent of front occupants. In comparison, NASS/CDS (N = 628) reported 9 percent (weighted estimate) nondeployment among front occupants killed. Among crashes common to both databases, NASS/CDS reported deployments for 45 percent of front occupant deaths for which FARS had coded nondeployments. Detailed case reviews of NASS/CDS crashes indicated highly accurate coding for deployment status. Based on this case review, 8 percent (weighted estimate) of front occupant deaths in frontal crashes appeared to involve air bag nondeployments; 1–2 percent of front occupant deaths represented potential system failures where deployments would have been expected. Air bag deployments appeared unwarranted in most nondeployments based on crash characteristics.*

Discussion: *FARS data overstate the magnitude of the problem of air bag deployment failures; steps should be taken to improve coding. There are inherent uncertainties in judgments about whether or not air bags would be expected to deploy in some crashes. Continued monitoring of air bag performance is warranted.*

Keywords Air bag; FARS; NASS/CDS; Traffic accidents; Motor vehicle deaths; Frontal crashes

INTRODUCTION

Front air bags prevent deaths in frontal collisions (Braver et al. 1997; Crandall et al. 2001; Cummings et al. 2002; Kahane 1996; Lund and Ferguson 1995; National Highway Traffic Safety Administration [NHTSA] 2001; Olson et al. 2006; Zador and Ciccone 1993). Front air bags work in tandem with seat belts to restrain front-seat occupants by inflating when sensors, measuring acceleration, indicate a moderate to severe frontal impact (Insurance Institute for Highway Safety 2008).

Recent media reports raised the possibility of widespread instances of front-seat occupants dying in crashes because front air bags failed to deploy. Based on data from the U.S. Fatality Analysis Reporting System (FARS), *The Kansas City Star* published a series of articles estimating that during 2001–2006, 1400 deaths occurred in frontal crashes in which air bags failed to deploy (Casey and Montgomery 2007a, 2007b). *The Kansas City Star* (Casey 2008) subsequently cited data from an internal NHTSA report based on deaths included in the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS), in which NHTSA (2008a) estimated that during 2001–2006, 576 people died in crashes in which front air bags did not deploy and that 360 of those who died would have benefited from front air bag protection.

As air bags became common in the vehicle fleet during 1988–1997, some people—particularly infants in rear-facing child safety seats, unrestrained older children, and short drivers sitting too close to deploying air bags—received air bag–induced

Received 15 July 2009; accepted 9 November 2009.
Address correspondence to: Elisa R. Braver, 3101 Quebec Place NW, Washington, DC 20008. E-mail: elisabraver@gmail.com

fatal or serious injuries during low-speed crashes that otherwise would not have resulted in major injury (Braver et al. 1997; Centers for Disease Control and Prevention 1996–1997; Durbin et al. 2003; Kahane 1996; NHTSA 2001; Office of the Federal Register 1997). Consequently, air bag designs were changed to reduce inflation energy (Kahane 2006). These redesigns have successfully reduced air bag–induced deaths among child passengers and do not appear to have compromised protection among adults (Arbogast et al. 2003, 2005; Augenstein and Digges 2003; Braver et al. 2005; Braver, Kufera, et al. 2008; Braver, Scerbo, et al. 2008; Ferguson and Schneider 2008; Kahane 2006; Olson et al. 2006; Schneider 2003; Segui-Gomez 2003; Segui-Gomez and Baker 2002).

For first-generation front air bags, crash test performance was certified by conducting 30 mph (48 km/h) head-on, full-frontal, rigid-barrier tests of unbelted 50th percentile male dummies. The next generation of air bags began with model year 1998, when NHTSA gave automobile manufacturers the option of certifying frontal crash performance for unbelted male dummies with 30 mph sled tests. The sled tests specified by the regulation had a longer crash pulse than rigid-barrier tests, enabling air bags to inflate with about 20–30 percent less energy (known as depowering; Kahane 2006).

A subsequent federal rule required automakers to phase in advanced air bags with features that would tailor deployment to crash severity and occupant characteristics such as seat belt status, occupant weight, seating position, and presence of rear-facing child seats (Office of the Federal Register 2001). The objective was improving protection both for unbelted and belted occupants. The latest generation of air bags generally deploys at higher crash severities for belted front occupants than for unbelted occupants, although this is not required by the standard, and includes dual-stage inflators that vary inflation by belt status and crash severity. For the remainder of this article, the latest generation of air bags will be referred to as certified-advanced air bags. Starting in model year 2003, some vehicles were equipped with certified-advanced air bags. By model year 2007, all new passenger vehicles were required to have certified-advanced air bags.

The primary objective of this study was to estimate the incidence of front air bag nondeployment in frontal crashes in which drivers or right-front passengers died. Another objective was to assess the completeness and accuracy of the information on air bag deployment in FARS, which is the leading source of data on fatal crashes in the United States.

METHODS

Data Sources

Two national U.S. databases, maintained by NHTSA, provided information on front air bag nondeployments in fatal frontal crashes. The first was FARS, a census of fatal crashes on U.S. public roads in which a death occurred within 30 days of the crash; documented suicides are excluded (NHTSA 1999–2007a). FARS data come from police crash reports, and the completeness and reliability of the data differ by variable, police agency, and individual officer. Although air bag deployment would appear to be readily verifiable by police officers at the crash scene, the accuracy of FARS coding of front air bag deployment has not been established.

The second database was NASS/CDS, a national probability sample of U.S. police-reported tow-away crashes (NHTSA 1999–2007b). NASS/CDS collects data for 5000 crashes annually, including a subset of FARS fatal crashes. NASS/CDS crash investigators collect detailed data including whether air bags deployed. Quality control centers provide oversight. Using both FARS and NASS/CDS, data on air bag deployments were obtained for drivers and right-front passengers fatally injured in crashes during 1998–2006 in air bag–equipped vehicles (model years 1994–2006).

Vehicle make, model, model year, and presence of front air bags were based on decoded vehicle identification numbers (VINs) contained in the federal databases. Vindicator software from the Highway Loss Data Institute (HLDI) was used for this purpose (HLDI 2006).

Additional sources of data were used to ascertain whether crash-involved vehicles had first-generation, sled-certified, or certified-advanced air bags (Braver, Kufera, et al. 2008). These sources included NHTSA brochures (NHTSA 1997–2006), an NHTSA (2008b) Web site, and the 1998–2000 National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) manual (NHTSA 2000).

Variable Definitions

Frontal collision. The study examined only front-seat occupants involved in frontal collisions, the type of crash in which front air bags are designed to provide protection. Each database had a different method of coding crash type. In FARS, frontal crashes were defined as having a principal impact of 11, 12, or 1 o'clock; if the principal impact was missing, then the initial impact clock position was used. In NASS/CDS, frontal crashes were those in which the general area of vehicle damage was coded as front for the most severe Collision Deformation Classification (crush profile; SAE International 1980).

Deployment. Nondeployment incidence in FARS and NASS/CDS was estimated after excluding occupants who were coded as having front air bags that had been disabled or removed or missing deployment information. In NASS/CDS, occupants were eligible for study only if a crash investigator had examined the vehicle.

Air bag generation. Air bag generations were defined as first generation (model years 1994–1997), sled-certified (model years 1998–2005 and reported as sled certified), or certified-advanced (model years 2003–2006 and reported as certified-advanced).

Data Analyses

The primary outcome was front air bag nondeployment following involvement in frontal crashes as coded by FARS and NASS/CDS. Chi-square tests of proportions were used for some comparisons. Data analyses were conducted using SAS 9.1

(SAS Institute 2003) and Microsoft Excel (Microsoft Corporation 2003).

To compare coding of air bag deployment status directly between FARS and NASS/CDS, front occupant fatalities contained in both databases were matched. Unique personal identifiers are not available from public data sets so other variables were used for matching. To be considered a valid match, FARS fatalities had to match NASS/CDS on crash year, state in which the crash occurred, seat position, crash month, and first 10 digits of the VIN. Cases also were required to match at least two of the following criteria: day of week, gender, and age within one year. In a small number of matched cases, the FARS VIN either was missing or was erroneous but similar to the NASS/CDS VIN. Ultimately, 1655 deaths of 1700 NASS/CDS deaths were identified in FARS (97% match rate).

Weighted NASS/CDS data were used to generate national estimates, and unweighted NASS/CDS data were used for comparisons of coding. All FARS front occupant deaths during 1998–2006 for model years 1994–2006 numbered 121,514, but NASS/CDS case weights for the same categories of front occupant deaths during that period totaled 85,869. Thus, NASS/CDS underrepresents the true number of U.S. deaths (ratio of FARS to NASS/CDS deaths = 1.415). To estimate numbers of front occupant deaths by deployment category, case weights in NASS/CDS were multiplied by 1.415 to account for NASS/CDS's underrepresentation of deaths.

Case Reviews

During 1998–2006 for model years 1994–2006, a total of 628 deaths among drivers and right-front passengers were coded as frontal in NASS/CDS. All of these cases were reviewed to verify deployment status. Three engineers, each with a minimum of 10 years of experience in this field, conducted comprehensive reviews of those deaths in which NASS/CDS coded nondeployment, disabled/removed air bag, or missing deployment status.

Information on each case was analyzed to determine whether an air bag would have been expected to deploy in that type of crash. The information used in this assessment included the delta V (change in velocity during the impact), crush pattern of the case vehicle, the object struck and its damage, comparison of damage to previously performed crash tests, and electronic data recorder (EDR) information in the three cases in which it was available. If the damage pattern suggested that the crash occurred at a delta V well above typical deployment thresholds, it was classified as "Expected to deploy." If the crash appeared to have occurred at a delta V that was close to typical deployment thresholds and its characteristics suggested that an air bag deployment would have been likely, it was classified as "Borderline." For those crashes in which the characteristics were such that the air bag likely was not designed to deploy, the crash was classified as "Not expected to deploy." This determination was made for non-frontal crashes, crashes with speeds (or acceleration pulses) believed to be below typical deployment thresholds, and crashes in which passenger vehicles underrode large trucks without having contacts below the greenhouse area.

In some air bag deployment systems, the algorithm turns off the system temporarily if the vehicle strikes an object with a severity below the deployment threshold. The purpose of this feature is to prevent the air bag from deploying when the occupant may have moved forward and thus be at risk of injury from the deploying air bag. This level of specificity could not be included in the case review. There is insufficient public information regarding the algorithms present in particular vehicles because the algorithms are proprietary information. There also is too little information regarding the timing of the specific crash events. Some nondeployments in this scenario may be warranted and prevent greater injury to the occupant. There also may be crashes in which the algorithm incorrectly interprets the crash scenario and prevents the deployment when it would be preferable for the air bag to deploy. Because these details cannot be accurately determined, the effect of multiple impacts was not included as a factor in the determination of the crash classification.

In addition to classifying crashes by whether an air bag would have been expected to deploy, the research engineers made a judgment as to whether the air bag might have benefited the fatally injured occupant if it had deployed. Air bag deployment was judged unlikely to have been able to prevent death in severe frontal crashes that caused occupant compartment collapse, particularly those that involved either a rollover or significant underride with primary damage above the tops of the doors. In addition, air bag deployments were considered unlikely to be able to prevent the deaths of occupants who were killed by objects intruding into the passenger compartment or who died as a result of medical conditions. In crashes that were uncomplicated and where the occupant compartment remained intact, deployments were classified as likely to have been beneficial.

RESULTS

Incidence of Nondeploying Air Bags

No differences were observed in deployments between drivers and right-front passengers, so they were combined for analyses (data not shown). After excluding deaths with missing air bag deployment data, FARS reported nondeployments in 18 percent of front occupant deaths in frontal crashes during 1998–2006 (Table I). NASS/CDS reported 9 percent nondeployment (weighted). In NASS/CDS, first-generation air bags had significantly lower nondeployments compared with sled-certified air bags (weighted 7% vs. 11%; $p < 0.001$). Statistical tests could not be performed for certified-advanced air bags because only 28 NASS/CDS deaths had these air bags.

Comparisons of Coding Among Front Occupant Deaths Included in Both FARS and NASS/CDS

Among the 1655 NASS/CDS front occupant deaths successfully matched to a FARS record, FARS classified 787 deaths as occurring in frontal crashes, whereas NASS/CDS classified 606 as frontal crashes (Table II). Thirty-two percent of crashes deemed to be frontal by FARS were considered non-frontal

Table I Coding of front air bag performance in frontal[a] crashes in which drivers or right-front passengers died by air bag generation,[b] FARS and NASS/CDS, model years 1994–2006, calendar years 1998–2006

	First generation		Sled-certified		Certified-advanced		All front air bags[c]	
Data source, deployment status	No.	%[d]	No.	%[d]	No.	%[d]	No.	%[d]
FARS (deaths)								
Deployed	14,496	84	18,548	81	1183	78	35,320	82
Not deployed	2858	16	4465	19	336	22	7849	18
Unknown	6823		6792		444		14,467	
Switched off/disabled	47		60		0		108	
Other	81		107		9		202	
Total	24,305		29,972		1972		57,946	
NASS/CDS (unweighted)								
Deployed	211	95	294	90	25	96	548	93
Not deployed	12	5	31	10	1	4	44	7
Unknown	13		12		2		27	
Switched off/disabled	5		4		0		9	
Total	241		341		28		628	
NASS/CDS (weighted)								
Deployed	10,149	93	15,547	89	813	96	27,414	91
Not deployed	782	7	1899	11	34	4	2714	9
Unknown	981		736		201		1918	
Switched off/disabled	103		245		0		348	
Total	12,015		18,427		1048		32,394	

[a]FARS: Frontal defined as 11, 12, 1 o'clock principal impact point (or initial impact point among 335 deaths where principal was missing); NASS/CDS: Frontal defined as principal area of damage from collision deformation classification.
[b]First-generation air bags: rigid barrier test (model years 1994–1997); sled-certified air bags: sled test (model years 1998–2005); certified advanced air bags: certified as advanced and compliant with federal standards for occupant crash protection (model years 2003–2006).
[c]Total also includes air bags that did not fall into air bag generation categories, such as those tested using rigid barriers after model year 1997.
[d]Percentages exclude missing air bag deployment data and inactivated air bags.

by NASS/CDS; differences were statistically significant ($p < 0.001$).

For the 538 deaths that were considered as occurring in frontal crashes by both databases, FARS and NASS/CDS agreed on air bag deployment status in 75 percent of the cases (Table III). Deployment coding differences in NASS/CDS versus FARS were statistically significant ($p < 0.001$). In this subset of matched cases, deployment status was coded as unknown in 21 percent of deaths in FARS and 5 percent in NASS/CDS. Of the 42 deaths where FARS coded a nondeployment, NASS/CDS reported that 19 (45%) air bags actually had deployed.

The accuracy of FARS deployment coding appeared to increase over time among the matched deaths based on agreement with NASS/CDS coding, although the increase was not significant using the Breslow-Day test of homogeneity. Among nondeployments coded by FARS, percentages that NASS/CDS coded as deployed were 67 percent during calendar years 1998–2000 versus 42 percent during 2004–2006 (data not shown).

Table II Comparison of principal impact point codes among front occupant deaths included in both FARS and NASS/CDS, model years 1994–2006, calendar years 1998–2006

	FARS coding					
	Frontal		Not frontal		Total	
NASS/CDS coding	No.	%	No.	%	No.	%
Frontal	538[a]	68	68	8	606	37
Not frontal	249	32	800	92	1049	63
Total	787	100	868	100	1655	100

[a] $\chi^2 = 651.54$, 1 df; $p < 0.001$.

Case Reviews of NASS/CDS Front Occupant Deaths and National Estimates by Deployment Status

After reviewing case photographs and other crash investigation records for all 628 NASS/CDS front occupant deaths coded as frontal during 1998–2006, four errors in deployment codes were identified: two air bags coded as nondeployed were switched off; one air bag coded as switched off was not switched off but was an instance of nondeployment; one air bag with unknown deployment status had been removed prior to the crash (Table IV). No deployment coding errors were observed among any front occupant deaths in which NASS/CDS indicated that front air bags had deployed. After accounting for the four coding errors, the weighted percentage of front occupant deaths involving an air bag nondeployment was 8 percent, and the weighted percentage with a switched off/removed air bag was 2 percent.

Of the 43 verified nondeployments, 25 were in crashes in which deployment typically would not be expected and 11 were in crashes in which deployment would have been expected based on crash severity and other characteristics (Table IV). An additional six deaths were classified as borderline, defined as crashes in which a deployment would not have been surprising but was not necessarily expected. The deployment classification for one nondeployment case could not be determined due to insufficient crash information.

Table III Comparison of front air bag deployment coding among front occupant deaths in NASS/CDS that were matched to FARS and coded as frontal crashes by both databases, model years 1994–2006, calendar years 1998–2006

	FARS Coding											
	Deployed		Not deployed		Off/disabled		Unknown		Non-frontal deployment		Total	
NASS/CDS Coding	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Deployed	369[a]	98	19	45	0	—	85	74	1	—	474	88
Not deployed	5	1	13	31	1	—	11	10	1	—	31	6
Off/disabled	0	0	6	14	1	—	1	1	0	—	8	1
Unknown	3	1	4	10	0	—	18	16	0	—	25	5
Total	377	100	42	100	2	—	115	100	2	—	538	100

[a] $\chi^2 = 221.36$, 12 df; $p < 0.001$.

Of the 11 deaths where deployments would have been expected, all but 3 likely would have benefited if front air bags had deployed (Table V). In the borderline cases, benefits from air bag deployments were considered unlikely for 4 of the 6 deaths because of passenger compartment intrusion and other crash characteristics.

After calculating case weights from NASS/CDS for deaths with nondeployed air bags by categories of nondeployment, the case weights were multiplied by 1.415 to yield adjusted national estimates (Table IV). The resulting estimates were 449 deaths in which air bags would have been expected to deploy and another 464 deaths classified as borderline expected deployments during 1998–2006. This yielded 50–101 annual deaths, on average, in which air bags did not deploy and were potential system failures during the 9-year study period.

Reasons for nondeployment among the 17 deaths where deployments would have been expected or were classified as borderline were unclear (Table V). One vehicle had an air bag recall issue that likely was the reason for nondeployment, whereas several vehicles had air bag recall issues that appeared unrelated to nondeployment. Repair histories could not be ascertained for air bags that had been recalled.

Several factors were responsible among the 25 vehicles in which the air bag was not expected to deploy. In 10 crashes, the most significant event was a rollover that followed a minor frontal crash, and in many cases the occupant was ejected during the rollover. Five vehicles had frontal crashes, but these were complete underrides with large trucks in which the vehicle hood was not contacted. Four crashes were more consistent with side impacts, and in 3 of these crashes the driver was ejected through the side window. In 3 of the crashes, the fatality was caused by a foreign object striking the driver through the windshield. Finally, in 3 crashes, the vehicle had sufficiently low delta V values that an air bag would not be expected to deploy. In 2 of these crashes, the fatality was possibly due to a preexisting medical condition.

Table IV Judgments regarding nondeployment, revised coding, and adjusted national estimates based on IIHS case reviews of front air bag performance in frontal crashes in which drivers or right-front passengers died, NASS/CDS, model years 1994–2006, calendar years 1998–2006

Deaths by deployment status	Original codes		IIHS judgments and revised codes and case weights		IIHS adjusted national estimates[a]	
	No.	%[b]	No.	%[b]	No.	%[b]
(Unweighted)						
Deployed	548	91	548[c]	91	—	—
Not deployed	44	7	43	7	—	—
Not expected to deploy	—	—	25	4	—	—
Expected to deploy	—	—	11	2	—	—
Borderline	—	—	6	1	—	—
Unknown	—	—	1	0	—	—
Unknown	27	—	26	—	—	—
Switched off/disabled	9	1	11	2	—	—
Total	628	100	628	100	—	—
(Weighted)						
Deployed	27,414	90	27,414	90	38,791	90
Not deployed	2,714	9	2,543	8	3,598	8
Not expected to deploy	—	—	1,890	6	2,674	6
Expected to deploy	—	—	317	1	449	1
Borderline	—	—	328	1	464	1
Unknown	—	—	8	0	11	0
Unknown	1,918	—	1,851	—	2,619	—
Switched off/disabled	348	1	586	2	829	2
Total	32,394	100	32,394	100	45,838	100

[a] NASS/CDS case weights were multiplied by 1.415 to address underrepresentation of deaths in NASS/CDS (based on ratio of FARS to NASS/CDS front occupant deaths).
[b] Percentages exclude missing data.
[c] Included 5 deaths in which vehicles had caught fire post-crash and NASS/CDS investigators judged that deployment had occurred, but extensive damage made photographs difficult to interpret by IIHS reviewers.

DISCUSSION

FARS data suggested that front air bags did not deploy in 18 percent of frontal crashes fatal to drivers and right-front passengers in cases where information on deployment was available. However, these were overestimates as indicated by-findings for fatal crashes included in NASS/CDS. Based on NASS/CDS case reviews, the percentage of nondeployments was revised downward to 8 percent; 1–2 percent of deaths represented potential system failures where deployment would have been expected and 2 percent involved air bags that had been disabled or removed. Some of these deaths could not have been prevented by deployed air bags.

Review of all 628 NASS/CDS front occupant deaths in frontal crashes during 1998–2006 indicated a high level of accuracy in the NASS/CDS coding of air bag deployment; only four errors

Table V IIHS case reviews of 43 driver and right-front passenger (RF Pass) frontal crash deaths with front air bags verified as not having deployed, NASS/CDS, model years 1994–2006, calendar years 1998–2006

Deployment classification based on case review	Possible reasons for nondeployment	Seat position	Air bag generation	Delta-V[a] mph (NASS/CDS)	Deployed air bag likely to have been beneficial?	Other comments	NASS/CDS case	Vehicle make/model	Model year
Expected to deploy	Air bag recall issue	Driver	Sled-certified		Yes	Passenger air bag deployed	2006-74-195B	Dodge Truck-Caravan Van	2000
Expected to deploy	Unknown	Driver	First generation		No	Passenger air bag deployed, although underride crash	2000-78-19A	Chevy/GEO-Lumina 4D	1997
Expected to deploy	Unknown	Driver	Sled-certified	40	Yes		2001-12-116A	GMC Truck-S15/Sonoma Pickup	2000
Expected to deploy	Unknown	RFPass	Sled-certified	19	Yes	Apparently unrelated air bag recall issue	2004-3-96B	Honda-Civic 2D Coupe	1998
Expected to deploy	Unknown	Driver	Sled-certified		Yes		2004-43-323B	Toyota-Tacoma PU X Cab	1998
Expected to deploy	Unknown	RFPass	Certified-advanced		Yes		2004-47-83A	Chevy/GEO Truck-Silverado 1500 PU E C	2003
Expected to deploy	Unknown	Driver	Sled-certified	29	Yes		2005-50-18B	Chevy/GEO-Cavalier 2D	1998
Expected to deploy	Unknown	Driver	Sled-certified		Unlikely		2006-3-121B	Honda-Accord 4D	2003
Expected to deploy	Unknown	Driver	First generation		Yes	Apparently unrelated air bag recall issue; Passenger air bag deployed	2006-43-149A	Mazda-Protégé 4D	1995
Expected to deploy	Unknown	Driver	Sled-certified	35	Yes		2006-78-47B	Daewoo-Lanos 4D	2000
Expected to deploy	Unknown	Driver	First generation	42	No	Incorrectly coded in NASS as vehicle not having air bag	2005-45-88B	Chevy/GEO-10/1500 Pickup 1/2 T	1996
Borderline	Unknown	Driver	First generation		Possibly	Oblique impacts	1998-45-165J	Honda-Accord 4D	1996
Borderline	Unknown	Driver	Sled-certified		No	Possible air bag recall issue; Driver side thorax air bag deployed	2000-76-139A	GMC Truck-Yukon 4D	2000
Borderline	Unknown	Driver	Sled-certified		No	Vehicle rolled over	2005-73-161B	Chevy/GEO Truck-Astro EXT Van	1999
Borderline	Unknown	Driver	First generation	16	Yes		2006-43-198B	GMC Truck-Suburban 1/2T 4D	1996
Borderline	Unknown	Driver	First generation		Unlikely	Vehicle rolled over	2006-45-117B	Chevy/GEO Truck-S10 Blazer 4D	1996
Borderline	Unknown	Driver	Sled-certified	18	No	Injuries due to intrusion directly into greenhouse	2006-50-83B	Hyundai-Tiburon 2D	2000
Not expected to deploy	Complete underride	Driver	Sled-certified		No		2000-43-243A	Chrysler/Plymouth Truck–Voyager Van	2000
Not expected to deploy	Complete underride	RFPass	Sled-certified		No		2000-45-160A	Toyota-Camry 4D	1998
Not expected to deploy	Complete underride	Driver	First generation		No		2001-73-41B	GMC Truck-Safari EXT Van	1994
Not expected to deploy	Complete underride	Driver	Sled-certified		No		2002-47-39A	Mazda-626 Sedan	1999
Not expected to deploy	Complete underride	Driver	First generation		No		2005-43-3B	Chevy/GEO Truck–T10 Blazer 4D	1997
Not expected to deploy	Foreign object	Driver	Sled-certified		No	Driver killed by object striking windshield prior to crash	2002-11-39J	GMC Truck-T15 Jimmy 4D	1999

(Continued on next page)

Table V IIHS case reviews of 43 driver and right-front passenger (RF Pass) frontal crash deaths with front air bags verified as not having deployed, NASS/CDS, model years 1994–2006, calendar years 1998–2006 *(Continued)*

Deployment classification based on case review	Possible reasons for nondeployment	Seat position	Air bag generation	Delta-V[a] mph (NASS/CDS)	Deployed air bag likely to have been beneficial?	Other comments	NASS/CDS case	Vehicle make/model	Model year
Not expected to deploy	Foreign object	Driver	Sled-certified		No	Snowmobile struck the vehicle in the greenhouse	2003-11-18A	Subaru-Forester 4D	2001
Not expected to deploy	Foreign object	Driver	Sled-certified		No	Fatality caused by fence post entering windshield and striking driver	2005-75-56B	Chevy/GEO-Cavalier 2D	1998
Not expected to deploy	Low delta-V	Driver	First generation	12	No	Reconstruction overestimates delta-V	1998-11-214B	Buick–LeSabre/Centurion/Wildcat	1994
Not expected to deploy	Low delta-V	Driver	First generation	11	No	Reconstruction overestimates delta-V	1998-12-40A	Chevy/GEO Truck-S10 Pickup	1995
Not expected to deploy	Low delta-V	Driver	Sled-certified	8	Unknown		2002-81-42A	Jeep-Grand Cherokee 4D	2000
Not expected to deploy	Rollover	Driver	Sled-certified		Unlikely	Driver ejected during rollover	2000-75-22A	Lexus-LX470 4D	1999
Not expected to deploy	Rollover	Driver	First generation		No	Driver ejected during rollover	2001-75-152B	Chevy/GEO Truck-S10 Pickup	1997
Not expected to deploy	Rollover	Driver	Sled-certified	7	No	Driver ejected during rollover	2002-45-157A	Ford Truck–Expedition 4D	2003
Not expected to deploy	Rollover	Driver	Sled-certified	2	No		2002-72-122A	GMC Truck-Envoy 4D	2002
Not expected to deploy	Rollover	RFPass	Sled-certified		No		2004-3-102A	Chevy/GEO-Impala 4D	2001
Not expected to deploy	Rollover	Driver	Sled-certified		No		2004-45-126A	Ford Truck-Ranger Super PU	2002
Not expected to deploy	Rollover	Driver	Sled-certified	5	No	Driver ejected during rollover	2004-73-142B	Ford Truck-Excursion 4D	2000
Not expected to deploy	Rollover	Driver	Sled-certified	11	Unlikely	Driver partially ejected during rollover	2006-8-181B	Chevy/GEO Truck-T10 Blazer 2D	2001
Not expected to deploy	Rollover	Driver	Sled-certified	7	No	Driver partially ejected during rollover	2006-42-149A	Kia-Sorento 4D	2004
Not expected to deploy	Rollover	RFPass	Sled-certified		No	Right front passenger ejected during rollover	2006-47-61A	Ford Truck- Ranger Pickup	2004
Not expected to deploy	Side impact	Driver	First generation		Unlikely	Driver ejected through window	1999-48-78B	GMC Truck-Yukon 4D	1995
Not expected to deploy	Side impact	Driver	First generation		No	Catastrophic intrusion	2000-78-26B	Chevy/GEO Truck-1500 PU EXT C 1/2T	1996
Not expected to deploy	Side impact	Driver	Sled-certified		Unlikely	Driver ejected and decapitated during complicated crash	2006-48-294B	Toyota-Tacoma PU	2000
Not expected to deploy	Side impact	Driver	Sled-certified		No	Driver ejected through driver door window	2006-50-12B	Chevy/GEO Truck-S10 Blazer 4D	2000
Unknown		Driver	Sled-certified			Not enough vehicle information for determination	2006-9-169A	Chevy/GEO-Aveo 4D	2004

[a]Longitudinal delta-V calculated by NASS/CDS program.

were detected in classifying deployment status. The strongest evidence of FARS overstatement of nondeployments arose from comparison of coding among fatal crashes included in both FARS and NASS/CDS, which indicated that half of the FARS deaths coded as nondeployments were misclassified. FARS deployment coding accuracy might be improving over time; among deaths included in both NASS/CDS and FARS, the agreement of FARS and NASS deployment codes improved between 1998–2000 and 2004–2006.

In a substantial number of front occupant deaths, FARS and NASS/CDS disagreed about whether the principal impact point was frontal, with NASS/CDS classifying fewer of them as frontal. Assuming that NASS/CDS codes principal impact point more accurately, one reason for FARS overestimates of air bag nondeployment in crashes considered as frontal by FARS is misclassification of non-frontal crashes as frontal by FARS. Because front air bags are not designed to deploy in non-frontal crashes, this likely resulted in inflated FARS percentages of nondeploying air bags in frontal crashes. Case reviews of nondeployments showed that NASS/CDS misidentified some crashes as frontal, although this would be expected to occur less often than in FARS because vehicles are inspected by crash investigators. The authors were unable to review all 1700 deaths in NASS/CDS to determine how often impact point was miscoded by NASS/CDS. National estimates of the numbers of deaths in frontal crashes in which air bags did not deploy could either be overstated or understated depending on the true frequency of fatal frontal crashes and their deployment status.

An additional problem with FARS was the high percentage of front occupants whose air bag deployment status was unknown. Missing data may result in inaccurate estimates of nondeployment. One implication is that studies of air bag effectiveness using FARS should use air bag presence rather than coded air bag deployment status because of missing and misclassified deployment data in FARS.

The inaccuracies in FARS may stem partly from the lack of uniformity among state police crash report forms and coding practices. Some states have air bag deployment as a separate variable on the police crash report forms; others do not. At least three states (Florida, Maryland, and Indiana) have a category known as “Safety Equipment” in which police are supposed to code air bags only if they deployed.

In NASS/CDS, nondeployments were significantly less common among first-generation air bags compared with sled-certified air bags. A limitation in any comparisons by air bag generation is that there may be differences in the distribution of vehicle types and crash characteristics, such as percentage that rolled over.

Match rates for deaths included in both FARS and NASS/CDS were high (97%) and were based on multiple variables, lessening the likelihood of inaccurate identification of fatal crashes. A limitation of the study was small numbers of deaths among occupants with certified-advanced air bags. Another limitation stems from the inherent uncertainties of researchers making judgments about whether or not an air bag would be expected to deploy in some crashes and whether air bag deployments in individual crashes would have reduced injury severity. Case reviews have inherent subjectivity and would involve a great deal of uncertainty if all crashes were near typical deployment thresholds. This study, however, is restricted to crashes in which an occupant was fatally injured, which usually occurs at delta Vs well above these typical deployment thresholds. Furthermore, three experienced engineers reviewed the cases using stringent criteria.

Since the first reports of air bag–induced fatalities started appearing, regulators, automobile manufacturers, and air bag manufacturers have been engaged in an effort to prevent such fatalities and injuries while designing air bags that deploy appropriately when front occupants need their protection. Different manufacturers have reached different conclusions on the optimal algorithms for triggering air bags and how to protect out-of-position occupants from deployment-related injuries. Several of the crashes involved minor frontal impacts prior to the most severe frontal crash, and the effects of these impacts on air bag systems are unknown. An air bag sensor could have detected an occupant who had moved close to the air bag following a minor collision and then suppressed deployment to prevent air bag–induced injuries. Certified-advanced air bags, which can suppress deployment or vary the degree of air bag inflation, are intended to balance protection versus risk to front occupants.

CONCLUSIONS

Failures of front air bags to deploy in crashes in which drivers or right-front passengers died and in which the front air bags usually would be expected to deploy appear to be relatively uncommon and far less frequent than suggested by FARS data. NHTSA should take steps to improve the accuracy of air bag deployment coding in FARS. Findings of this study were consistent with the internal NHTSA (2008a) analysis (Casey 2008). Nonetheless, the estimated number of front occupant deaths in which front air bags were expected to deploy is of concern. Examination of air bag system components and further in-depth investigations of vehicles with nondeployments would be useful to help shed light on what is occurring and whether there are possible countermeasures. Continued monitoring of front air bag performance is warranted, particularly for the newest generation of advanced air bags that are designed to optimize front air bag deployment. Another concern is the substantial number of air bags that had been disabled or removed; this problem needs more attention.

ACKNOWLEDGMENTS

This work was supported by the Insurance Institute for Highway Safety. Partial support was provided by the Crash Injury Research and Engineering Network center at the University of Maryland School of Medicine in Baltimore. From the Insurance

Institute for Highway Safety, we are grateful to Joe Nolan for providing expert advice on the case reviews and to Laura Strouse for providing research assistance. From the University of Maryland, Baltimore, we are grateful to Shiu M. Ho for providing advice on matching and computer programming and to Joseph P. Lloyd for providing technical advice on vehicle features and crash investigation.

REFERENCES

Arbogast KB, Durbin DR, Kallan MJ, Elliott MR, Winston FK. (2005) Injury Risk to Restrained Children Exposed to Deployed First- and Second-Generation Air Bags in Frontal Crashes. *Arch. Pediatr. Adolesc. Med.*, Vol. 159, pp. 342–346.

Arbogast KB, Durbin DR, Kallan MJ, Winston FK. (2003) Effect of Vehicle Type on the Performance of Second Generation Air Bags for Child Occupants. *Proc. 47th Annual Association for the Advancement of Automotive Medicine*, pp. 85–99.

Augenstein J, Digges K. (2003) Performance of Advanced Air Bags Based on Data William Lehman Injury Research Center and New NASS PSUs. Proc. *47th Annual Association for the Advancement of Automotive Medicine*, pp. 99–101.

Braver ER, Ferguson SA, Greene MA, Lund AK. (1997) Reductions in Deaths in Frontal Crashes Among Right Front Passengers in Vehicles Equipped with Passenger Air Bags. *JAMA*, Vol. 278, pp. 1437–1439.

Braver ER, Kufera JA, Alexander MT, Scerbo M, Volpini K, Lloyd JP. (2008) Using Head-on Collisions to Compare Risk of Driver Death by Frontal Air Bag Generation: A Matched-Pair Cohort Study. *Am. J. Epidemiol.*, Vol. 167, pp. 885–886.

Braver ER, Kyrychenko SY, Ferguson SA. (2005) Driver Mortality in Frontal Crashes: Comparison of Newer and Older Airbag Designs. *Traffic Inj. Prev.*, Vol. 6, pp. 24–30.

Braver ER, Scerbo M, Kufera JA, Alexander MT, Volpini K, Lloyd JP. (2008) Deaths among Drivers and Right-Front Passengers in Frontal Collisions: Redesigned Air Bags Relative to First-Generation Air Bags. *Traffic Inj. Prev.*, Vol. 9, pp. 48–58.

Casey M. (2008) Federal Agency to Keep Airbag Regulations. *The Kansas City Star*, February 4, p. A1.

Casey M, Montgomery R. (2007a) Airbags Raise New Alarms—Some Didn't Deploy in Fatal Crashes, Newspaper Learns. *The Kansas City Star*, October 21, p. A1.

Casey M, Montgomery R. (2007b) Front Airbags Don't Inflate in Hundreds of Head-on Crashes. *The Kansas City Star*, October 22, p. A1.

Centers for Disease Control and Prevention. (1996–1997) Update: Fatal Airbag-Related Injuries to Children—United States, 1993–1996. *MMWR Morb. Mortal. Wkly. Rep.*, Vol. 45(49), pp. 1073–1076. Erratum published in *MMWR Morb. Mortal. Wkly. Rep.*, Vol. 46(2), p. 40.

Crandall CS, Olson LM, Sklar DP. (2001) Mortality Reduction With Air Bag and Seat Belt Use in Head-on Passenger Car Collisions. *Am. J. Epidemiol.*, Vol. 153, pp. 219–224.

Cummings P, McKnight B, Rivara FP, Grossman DC. (2002) Association of Driver Air Bags With Driver Fatality: A Matched Cohort Study. *Br. Med. J.*, Vol. 324, pp. 1119–1122.

Durbin DR, Kallan M, Elliott M, Cornejo RA, Arbogast KB, Winston FK. (2003) Risk of Injury to Restrained Children From Passenger Air Bags. *Traffic Inj. Prev.*, Vol. 4, pp. 58–63.

Ferguson SA, Schneider LW. (2008) An Overview of Frontal Air Bag Performance With Changes in Frontal Crash-Test Requirements: Findings of the Blue Ribbon Panel for the Evaluation of Advanced Technology Air Bags. *Traffic Inj. Prev.*, Vol. 9, pp. 421–431.

Highway Loss Data Institute. (2006) *Vindicator 2006*, Release 1. Highway Loss Data Institute, Arlington, VA.

Insurance Institute for Highway Safety. (2008) *Q&As: Airbags*. Arlington, VA. Available at: http://www.iihs.org/research/qanda/airbags.html (accessed July 8, 2009).

Kahane CJ. (1996) *Fatality Reduction by Air Bags: Analyses of Accident Data Through Early 1996*. National Highway Traffic Safety Administration, Washington, DC. Report no. DOT HS-808-470.

Kahane CJ. (2006) *An Evaluation of the 1998–1999 Redesign of Frontal Air Bags*. National Highway Traffic Safety Administration, Washington, DC. Report no. DOT HS-810-685.

Lund AK, Ferguson SA. (1995) Driver Fatalities in 1985–1993 Cars With Airbags. *J. Trauma*, Vol. 38, pp. 469–475.

Microsoft Corporation. (2003) *Excel 2003*. Microscoft Corp., Redmond, WA.

National Highway Traffic Safety Administration. (1997–2006) *Buying a Safer Car*. US Department of Transportation, Washington, DC. Brochure.

National Highway Traffic Safety Administration. (1999–2007a) *Fatality Analysis Reporting System, 1999–2007*. U.S. Department of Transportation, Washington, DC.

National Highway Traffic Safety Administration. (1999–2007b) *National Automotive Sampling System/Crashworthiness Data System, 1999–2007*. U.S. Department of Transportation, Washington, DC.

National Highway Traffic Safety Administration. (2000) *National Automotive Sampling System/Crashworthiness Data System—2000 Coding and Editing Manual*. U.S. Department of Transportation, Washington, DC.

National Highway Traffic Safety Administration. (2001) *Fifth/Sixth Report to Congress: Effectiveness of Occupant Protection Systems and Their Use*. U.S. Department of Transportation, Washington, DC. Report no. DOT HS-809-442.

National Highway Traffic Safety Administration. (2008a) *Fatalities in Frontal Crashes without Air Bag Deployment: Review of FARS and CDS Data*. PowerPoint presentation from National Center for Statistics and Analysis. Unpublished.

National Highway Traffic Safety Administration. (2008b) *Safercar.gov—Quick Facts: Frontal and Advanced Airbags*. U.S. Department of Transportation, Washington, DC.

Office of the Federal Register. (1997) National Highway Traffic Safety Administration—Final Rule. Docket no. NHTSA 74-14, Notice 114; 49 CFR Part 571—Federal Motor Vehicle Safety Standards, Occupant Crash Protection. *Federal Register*, Vol. 62(53), pp. 12960–12975.

Office of the Federal Register. (2001) *Code of Federal Regulations; Title 49 Transportation, Part 571 Federal Motor Vehicle Safety Standards, Standard No. 208 Occupant Crash Protection*. National Archives and Records Administration, Washington, DC.

Olson CM, Cummings P, Rivara FP. (2006) Association of First- and Second-Generation Air Bags With Front Occupant Death in Car Crashes: A Matched Cohort Study. *Am. J. Epidemiol.*, Vol. 164, pp. 161–169.

SAE International. (1980) *Collision Deformation Classification*. SAE International, Warrendale, PA. Document J224.

SAS Institute, Inc. (2003) *SAS* 9.1. SAS Institute, Cary, NC.

Schneider L. (2003) Comparison of Frontal Crash Protection for Front Seat Occupants in Pre-1998 and 1998 and Newer Model Vehicles. *Proc. 47th Annual Association for the Advancement of Automotive Medicine*, pp. 81–83.

Segui-Gomez M. (2003) Changes in Injury Patterns in Frontal Crashes: Injuries to Drivers of Vehicles Model Year 1993–1997 vs. Drivers of Vehicles 1998–2002—An Analysis of NASS/CDC Data. *Proc. 47th Annual Association for the Advancement of Automotive Medicine*, p. 84.

Segui-Gomez M, Baker SP. (2002) Changes in Injury Patterns in Frontal Crashes: Preliminary Comparisons of Drivers of Vehicles Model Years 1993–1997 to Drivers of Vehicles 1998–2001. Proc. *46th Annual Association for the Advancement of Automotive Medicine*, pp. 1–14.

Zador PL, Ciccone MA. (1993) Automobile Driver Fatalities in Frontal Impacts: Air Bags Compared With Manual Belts. *Am. J. Publ. Health*, Vol. 83, pp. 661–666.