U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
www.nhtsa.gov

DOT HS 811 834

September 2013

Evaluation of the Certified-Advanced Air Bags

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Suggested APA Format Citation:

Greenwell, N. K. (2013, September). *Evaluation of the certified-advanced air bags*. (Report No. DOT HS 811 834). Washington, DC: National Highway Traffic Safety Administration.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 811 834		

4. Title and Subtitle	5. Report Date
Evaluation of the Certified-Advanced Air Bags	September 2013
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Nathan K. Greenwell	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Evaluation Division; National Center for Statistics and Analysis National Highway Traffic Safety Administration Washington, DC 20590	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590	NHTSA Technical Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The purpose of this report is to analyze the changes and redesigns of frontal air bags and their effect on occupant protection in frontal crashes. Frontal air bags have gone through a series of changes in response to amendments to Federal Motor Vehicle Safety Standard No. 208, "Occupant crash protection." In 1998-1999, vehicle manufacturers were permitted to sled test in lieu of a barrier impact to certify that the air bags would protect an unbelted occupant ("sled certification"), which allowed air bags to be redesigned by depowering and/or reducing the volume or rearward extent of air bags. Then in 2003-2006, air bags were required to not deploy at all for children or deploy only at a low level of force ("certified-advanced air bags"). Most manufacturers chose to not deploy air bags at all for children, using occupant detection sensors to suppress the air bags. Statistical analyses of crash data from NHTSA's Fatality Analysis Reporting System (FARS) and R.L. Polk's National Vehicle Population Profile (NVPP) compare fatality risk with certified-advanced and sled-certified air bags.

- Fatality risk in frontal crashes was 4 percent lower for drivers with certified-advanced air bags than with sled-certified air bags; for right-front passengers, it was 2 percent higher; at neither position is the difference between certified-advanced and sled-certified air bags statistically significant.
- The fatality rate, in frontal crashes per billion vehicle registration years showed a 4 percent reduction overall, 5 percent reduction for drivers, and 5 percent reduction for child right-front passengers 12 and younger, after vehicles were equipped with certified-advanced air bags. None of these were statistically significant.

Overall, the analysis found no evidence that certified-advanced air bags result in higher fatality risk to front-seat occupants in frontal crashes when compared to sled-certified air bags.

17. Key Words	18. Distribution Statement
NHTSA; FARS; Special Crash Investigations; FMVSS; statistical analysis; evaluation; effectiveness; fatality reduction; crashworthiness; sled certification; certified-advanced air bags	Document is available to the public from the National Technical Information Service www.ntis.gov

19. Security Classif. (Of this report)	20. Security Classif. (Of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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List of Abbreviations

ATD	anthropomorphic test device (dummy)
CAC	Certified Advanced Compliant
CDS	Crashworthiness Data System (a sample of crashes in the United States since 1979)
CY	calendar year
CIREN	Crash Injury Research and Engineering Network
ESC	electronic stability control
FARS	Fatality Analysis Reporting System (a census of fatal crashes in the United States since 1975)
FMVSS	Federal Motor Vehicle Safety Standard
GVWR	gross vehicle weight ratio
HLDI	Highway Loss Data Institute
IIHS	Insurance Institute for Highway Safety
LTV	light trucks and vans (includes pickup trucks, SUVs, minivans, and full-sized vans)
MY	model year
NHTSA	National Highway Traffic Safety Administration
NVPP	R. L. Polk's National Vehicle Population Profile
RF	right-front
SCI	Special Crash Investigations by NHTSA's National Center for Statistics and Analysis
SDS	State Data System
SUV	sport utility vehicle
VIN	Vehicle Identification Number

Executive Summary

This report analyzes the changes and redesigns of frontal air bags and their effect on occupant protection in frontal crashes. Specifically, the report addresses the frontal crash mortality rates between vehicles certified to a temporary option in Federal Motor Vehicle Safety Standard No. 208, "Occupant crash protection," allowing unbelted certification through a sled test, and the "advanced" air bag requirements in FMVSS No. 208.

Frontal air bags were designed to protect restrained and unrestrained occupants, but in the early 1990s, they were found to harm occupants positioned too close to the air bag at the time of deployment. By late 1995, it was evident that not only infants, but also unrestrained children and even some adults were injured by frontal air bags. Therefore, NHTSA initiated interim and long-term actions to reduce and eventually eliminate the adverse effect of frontal air bags for infants, children and other high-risk occupants while retaining the benefits of air bags for most people.

The interim effort took effect on March 19, 1997, introducing a 48 km/h (30 mph) change in vehicle velocity (delta-V) unbelted sled test option in lieu of the existing 48 km/h (30 mph) unbelted barrier-crash test certification requirements. The new test facilitated sled-certified air bags that deploy less forcefully. The long-term effort resulted in "advanced" air bags that could deploy at a low level of force, depending on the occupant and crash conditions, or provide the option of suppressed deployment of the passenger air bag. Advanced air bags were phased into the fleet starting September 1, 2003, and were required in all new passenger cars, multipurpose passenger vehicles, buses, and trucks with a GVWR of 8,500 pounds or less and an unloaded vehicle weight of 5,500 pounds or less by September 1, 2006.

The long-term effort – the advanced air bags phased in from 2003 to 2006 – is the focus of this report. In 2010, the Insurance Institute for Highway Safety issued a paper that showed that the mortality rate was higher for drivers having certified-advanced air bags compared with sled-certified air bags.[1] This report follows up on the IIHS paper by analyzing additional crash data that has since become available; IIHS captured 644 front-seat fatalities in frontal crashes of vehicles equipped with certified-advanced air bags, while this report analyzes 2,573 fatalities of the same conditions. The Fatality Analysis Reporting System, a census of fatal crashes, provided data to compare overall fatality risk in frontal crashes before and after certification to the advanced air bag requirements. The R. L. Polk's National Vehicle Population Profile provided exposure data that made it possible to calculate the number of occupant fatalities in frontal crashes per vehicle registration years. This data was collected for each model's last three model years before and also the first three model years after certification to the advanced air bag requirements.

The principal analysis technique computes occupants' fatality risk in frontal crashes relative to control groups of crashes that were fatal only to pedestrians and bicyclists. The results show that the overall fatality rate for occupants in the front row of seating in frontal crashes resulted in a 3-percent reduction with certified-advanced air bags relative to sled-certified air bags. Breaking down the occupants by drivers and right-front passengers resulted in a 4-percent reduction for

[1] Braver, E. R., Shardell, M., & Teoh, E. R. (2010, February). *How Have Changes in Air Bag Designs Affected Frontal Crash Mortality*? Arlington, VA: Insurance Institute for Highway Safety.

drivers' fatality risk and a 2-percent increase in fatality risk for right-front passengers. However, none of these differences were statistically significant. The fatality rate, in frontal crashes per billion vehicle registration years showed a 4-percent reduction overall, 5-percent reduction for drivers, and 5-percent reduction for child right-front passengers up to 12 years old, after vehicles were equipped with certified-advanced air bags. None of these were statistically significant. The overall fatality risk of right-front passengers up to 12 years old in frontal crashes per billion vehicle registration years with certified-advanced air bags and with sled-certified air bags were far lower than with pre-1998, which had air bags and were certified to full frontal crash tests into a rigid barrier. Overall, results show no evidence that certified-advanced air bags result in a higher fatality risk to front seat occupants in frontal crashes when compared to sled-certified air bags.

Introduction

Redesign of Frontal Air Bags

The first generation of air bags was designed to protect unrestrained occupants as well as restrained occupants in frontal crashes. On July 17, 1984, NHTSA amended FMVSS No. 208, "Occupant crash protection," to phase in automatic protection, such as air bags or automatic belts, into the front-outboard seats of passenger cars between September 1, 1986, and September 1, 1989. To encourage the development of air bags, NHTSA exempted the right-front seat from the automatic protection requirement until August 31, 1993, in cars equipped with driver air bags. During the implementation of automatic protection, automatic belts initially dominated, then driver air bags with manual 3-point belts, and, after September 1, 1993, driver and front-passenger air bags with manual 3-point belts. These air bags were certified with an impact at any speed up to 48 km/h (30 mph) into a fixed rigid barrier that is perpendicular to the line of travel of the vehicle, and at any angle up to 30 degrees in either direction from the perpendicular to the line of travel of the vehicle with both belted and unbelted 50th percentile adult male anthropomorphic test device (ATD) in driver and right-front passenger positions.

On March 19, 1997, NHTSA amended FMVSS No. 208 (with an immediate effective date) relaxing some aspects of the frontal impact test for the unbelted ATD in order to facilitate the introduction of changes to air bags that allow them to deploy less forcefully or be "depowered."[2] This amendment consisted of the introduction of a sled test option in lieu of the 0-48 km/h (0-30 mph) unbelted crash test, also at 48 km/h (30 mph) with a standardized crash pulse lasting 125 milliseconds, a substantially more gradual deceleration than the barrier test on a typical vehicle.[3] This sled test replaced the full frontal and oblique crash tests into a rigid barrier with unbelted ATDs. Depowered air bags were introduced in 1998 models by removing some of the gas-generating propellant or stored gas from their inflators, adding vents, reducing the air bag size, or other means. Make-models became "sled-certified" when the manufacturer chose the sled test option whether or not the air bag was actually redesigned.

On May 12, 2000, NHTSA amended FMVSS No. 208 to phase in certified advanced 208-compliant (CAC) air bags (simply called "advanced " air bags in the rest of this report), from September 1, 2003, to September 1, 2006. This amendment added a wider variety of tests (full frontal, offset front, out-of-position scenarios) and larger span of occupant sizes. The agency adopted an unbelted crash test requirement with a 50th percentile adult male ATD that includes an oblique impact with a fixed rigid barrier. The unbelted test may be conducted at any speed between 32 km/h (20 mph) and 40 km/h (25 mph) into a barrier that is perpendicular to the line of travel of the vehicle or at any angle up to 30 degrees in either direction to simulate an oblique crash. Also for the first time, the standard would require protection for small-stature adults represented by a belted 5th percentile female Hybrid III ATD. One test with the 5th percentile female Hybrid III ATD is unbelted and matches the condition for the 50th percentile male unbelted test, except it is a perpendicular-barrier impact. The other test with the 5th percentile female Hybrid III ATD is a 0-48 km/h (0-30 mph) perpendicular-barrier test – in addition to a

[2] *Federal Register* 62 (March 19, 1997): 12960; *Code of Federal Regulations*, Title 49, Part 571.208 S13.
[3] Kahane, C. J. (2006, August). *An Evaluation of the 1998-1999 Redesign of Frontal Air Bags.* (Report No. DOT HS 810 685). Washington, DC: National Highway Traffic Safety Administration.

test with a belted 50th percentile adult Hybrid III male ATD under the same conditions, that between September 1, 2007, and September 1, 2010, would phase in to a 56 km/h (35 mph) maximum speed. On August 31, 2006, the agency further amended FMVSS No. 208 to increase the maximum test speed for the belted perpendicular-barrier test using the 5th percentile female Hybrid III ATD from 48 km/h (30 mph) to 56 km/h (35 mph). This amendment was phased in from September 1, 2009, to September 1, 2012.[4]

Lastly, amendments to FMVSS No. 208 added requirements for the different options for the driver and passenger air bag system. For the driver air bag, requirements were made for low risk deployment using the 5th percentile female ATD. For the passenger air bag there were three options, each to minimize the risk of deploying air bags to out-of position children. Certified-advanced air bags could not deploy at all for children ("suppression"), deploy only at a low level of force ("low-risk deployment"), or track an occupant's motion and suppress the air bag if they are too close ("dynamic automatic suppression").[5] For low risk deployment in passenger air bag, requirements were made using 1, 3, and 6 year-old ATDs. To date, the last option of dynamic automatic suppression, which requires the development of a test procedure through the submission of an acceptable rulemaking petition, has never been implemented.[6]

Previous Analysis on Frontal Air Bags

IIHS has completed an analysis[7] on whether front air bag changes have affected occupant protection. The analysis uses a Poisson marginal structural model to estimate and compare the frontal crash mortality rates (deaths per registered vehicle) among front outboard occupants in vehicles having certified-advanced air bags or sled-certified air bags with and without advanced features.

The calculated fatality rates were gathered for model years 1994-2006 during calendar years 2004-2007 for the following data sources: FARS for fatal crash cases; R.L. Polk for vehicle registrations; and Highway Loss Data Institute for age and gender distributions of insured drivers by make/model, model year, and calendar year. Analyses were restricted to vehicles remaining on the same engineering platform and having the same ESC status (standard or not) before and after receipt of CAC air bags.

The results showed that the vehicle age-corrected mortality rate was higher for drivers having certified-advanced air bags compared with sled-certified air bags with advanced features and even higher for belted drivers. On the other hand, child right-front passengers had lower unadjusted mortality rates with certified-advanced air bags than with sled-certified air bags with advanced features. IIHS concluded that the findings for certified-advanced air bags compared to sled-certified air bags with advanced features suggest potential problems with requirements for advanced air bag certification.

[4] *Federal Register* 71 (August 31, 2006): 57168: *Code of Federal Regulations*, Title 49, Part 571.208 S14.
[5] *Federal Register* 65 (May 12, 2000): 30679; *Code of Federal Regulations*, Title 49, Part 571.208 S14.
[6] Title 49, Part 552, Subpart B.
[7] Braver, Shardell, & Teoh (2010).

Goal of the Evaluation

The goal of this analysis is to determine the fatality-reduction benefits of certified-advanced air bags in comparison to sled-certified air bags. With IIHS results showing increased mortality rates for drivers having certified-advanced air bags compared to sled-certified air bags, it is important to analyze the changes of certified-advanced air bags and their effect on occupant protection, especially front seat occupants in frontal crashes.

Methods to Analyze the Effects of Certified-Advanced Air Bags

Selection of Vehicle Models

According to section 14.1.1 of FMVSS No. 208, the phase-in schedule of certified-advanced air bags required compliance for at least 20 percent of vehicles of model year (MY) 2004, 65 percent for MY 2005, 100 percent for MY 2006 allowing the use of credits and finally all MY 2007 vehicles. Before certified-advanced air bags, manufacturers added dual-stage inflators and other advanced features to many of their sled-certified air bags. The advanced features ranged from multi-stage inflators, buckle switches, seat weight sensors, seat belt usage sensors, to seat track sensors. NHTSA compiled a list and made a determination when the frontal air bags transitioned to certified-advanced air bags from sled-certified air bags with or without advanced features. The Appendix lists the vehicle make-models of passenger cars and LTVs included in the analyses and the range of model years included for each make-model.

Vehicle make-models selected for the study followed similar guidelines for how IIHS selected vehicles. Make-models had to have existed prior to being certified to the advanced air bag requirements. Make-models were restricted to those that remained on the same engineering platform before and after the transition to certified-advanced air bags. In addition, make-models were also restricted to have the same electronic stability control status (standard or not) during the transition.[8]

Due to limitations in determining what type of frontal air bags vehicles were certified to, the model year was limited to 2002 and forward. The analysis compared model years before to model years after the certification to certified-advanced air bags. The analysis also limited the number of model years to be matching between the before and after certification: up to the last 3 model years before and the first 3 model years after certification to certified-advanced air bags. For example, Dodge Grand Caravan and Ford Focus were certified to the advanced air bag requirements in 2005; the Appendix shows that MY 2002 to 2004 (pre-CAC) and 2005 to 2007 (CAC) are included in the analyses. If certification to advanced air bags began mid-year then that year was excluded and the three model years before and after it were included– e.g., because Mercury Grand Marquis was certified to the advanced air bag requirements in mid-2005, the analyses include 2002-2004 and 2006-2008 but exclude all of the 2005s.

The appendix provides a list of 117 selected make-models, model years, and their corresponding air bag certification type. Out of the 117 selected, 85 make-models transitioned from sled-certified with advanced features to certified-advanced airbags. The remaining 32 make models transitioned directly from sled-certified without advanced features to certified-advanced. The features considered advanced ranged from multi-stage inflators, buckle switches, seat weight sensors, seat belt usage sensors, to seat track sensors.

[8] However, for certain vehicles, a certain percentage per model year were equipped with ESC, and the difference in ESC percentage was miniscule, and, therefore these vehicles were not removed. An example with a small difference in the ESC percentage per model year during the transition to certified-advanced air bags is the Mazda RX-8. From MY 2004-2005 the vehicle is sled-certified with advanced features with an ESC percentage of 68 percent and 70 percent per model year, respectively, while for MY 2006-2007 equipped with certified-advanced air bags provided ESC in 70 percent and 71 percent of the model years, respectively. The difference is not of huge significance and therefore the vehicles are included in the study.

Methods for Analysis

Frontal fatalities relative to non-occupant fatalities

One approach is to consider non-occupant fatalities a control group and to calculate the change in frontal fatalities relative to the control group. These "non-occupant fatalities" are the pedestrians, bicyclists and other non-motorists struck and fatally injured by cars and LTVs of the make-models and model year ranges selected for this study. For any given group of vehicles, the analysis considers the ratio of fatalities who were front seat occupants in frontal impacts in the vehicles to the fatalities among pedestrians, bicyclists and other non-motorists who were struck by vehicles from this group.

The use of non-occupant fatalities as a control group was originally suggested to NHTSA by Dainius J. Dalmotas.[9] This control group is particularly useful when changes to included vehicles concurrent to the technology being evaluated may be biasing other types of occupant fatalities commonly used as a control group. For example, using side-impact and rollover fatalities as a control group in this analysis may yield a biased result due to changes in side air bags, vehicle stability, etc. that occurred at the same time as the transition to CAC air bags. With the non-occupant control group, we may analyze the actual, unadjusted fatality counts from FARS. We can use conventional statistical tests, such as chi-square. These analyses will include data starting the calendar year following the initial model year of certification to certified-advanced air bags and ending in CY 2011. For example, Dodge Caravan and Ford Focus certified in 2005; the analyses include crashes of MY 2002 to 2004 (pre-CAC) and MY 2005 to 2007 (CAC) in CY 2006 to 2011.

Frontal fatalities relative to non-frontal fatalities

Another method is based on a distinctive characteristic of air bags: they are primarily designed for action in frontal crashes. In a crash where no impact has a frontal force component, air bags are unlikely to deploy. They can be assumed to have essentially no effect, positive or negative. These fatalities in non-frontal crash involvements are a control group.

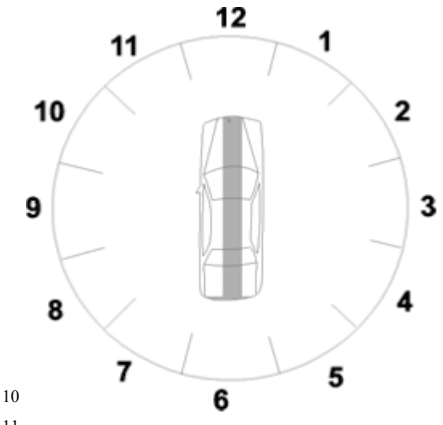
In FARS, we may define non-frontal crash involvements to include first-event rollovers and non-collisions, plus purely side or rear impacts (initial and principal impact locations between 3:00

[9] Kahane, C. J. (2007, January). *An Evaluation of Side Impacts Protection: FMVSS 214 TTI(d) Improvements and Side Air Bags.* (Report No. DOT HS 810 748). Washington, DC: National Highway Traffic Safety Administration, pp. 59-63.

and 9:00[10]). "Frontal" crashes have initial or principal impact between 11:00 and 1:00 (excluding first-event rollovers and non-collisions). Slightly frontal impacts with initial or principal impact at 10:00 or 2:00, but no impact at 11:00 to 1:00 are withheld from the analysis. This method was used in NHTSA's evaluation of sled-certified air bags relative to barrier-certified air bags.[11] All analyses with this method will use the same make-models, model years, and FARS calendar years as the analyses with the non-occupant control groups.

Frontal fatalities per vehicle registration years

This method will use fatality counts from FARS and registration data from R.L. Polk's NVPP, which specifies the number of vehicles of any make-model and model year that were registered as of July 1 of any calendar year. Similar to the analysis of frontal fatalities relative to non-occupant or non-frontal, fatality rates are compared before and after redesign and data is gathered starting the calendar year following the initial model year of certification to certified-advanced air bags. However, the one noteworthy difference is that for each model year, the data will be restricted to calendar years greater than the model year. The reason for this is because new vehicles initially are registered at varying times throughout the year they are sold (when MY ≥ CY), so the NVPP count of registrations as of July 1 may not accurately reflect the actual exposure during that year. Thus, Dodge Caravan and Ford Focus for MY 2002 to 2004 (pre-CAC) and MY 2005 (CAC) will include data for CY 2006 to 2011, but for MY 2006, only CY 2007 to 2011 and for MY 2007, only CY 2008 to 2011. In other words, the CY 2006 data for MY 2006 and the CY 2006 and 2007 data for MY 2007 are the only deletions from the preceding analyses of frontal fatalities relative to control-group fatalities.



[10]

[11] Kahane, C. J. (2006, August).

The 2×2 Contingency Table

For the above listed methods for analysis, the following example table is the method that will be used to estimate the effectiveness of certified-advanced air bags relative to sled-certified air bags with or without advanced features.

	Frontal Fatalities	Control Group	Frontal/Control Risk Ratio
Sled-certified with or without advanced features	N_{11}	N_{12}	N_{11}/N_{12}
Certified-advanced air bags	N_{21}	N_{22}	N_{21}/N_{22}

The number of control-group fatalities is a surrogate for the "exposure" of a group of vehicles. The certified-advanced air bags have N_{22}/N_{12} times as much exposure as vehicles not equipped with certified-advanced air bags. Based on this exposure ratio, the expected number of frontal fatalities for vehicles equipped with certified-advanced air bags is $(N_{22}/N_{12}) \times N_{11}$. In fact, there are only N_{21} vehicles equipped with certified-advanced air bags. With this information, certified-advanced air bags will experience a percent reduction or increase of:

$$1 - [(N_{21}/N_{22})/(N_{11}/N_{12})]$$

in frontal fatalities. The fatality reduction or increase is determined to be statistically significant, as evidences by a Chi- square (χ^2) test; χ^2 must exceed 3.84 for statistical significance at the .05 level.

Effects of Certified-Advanced Air Bags on Overall Fatality Risk in Frontal Crashes

Frontal Fatalities Relative to Non-Occupant Fatalities

An odds ratio was computed using frontal impacts as the treatment group and pedestrian and bicyclist fatalities as the control group. As stated above, crash data for any make-model included in the study was gathered starting the calendar year following the initial model year of certification up to CY 2011. Table 1 provides three 2×2 contingency tables: the first includes all makes and models in the database; the second is limited to models that transitioned directly from sled-certified without advanced features to certified-advanced; the third is limited to the models that transitioned from sled-certified with advanced features to certified-advanced air bags.

Table 1: Overall Effect of Certified-Advanced Air Bags

	Frontal Fatalities	Non-Occupant Fatalities	Frontal/Non-Occupant Risk Ratio
Sled-certified with or without advanced features	3,004	1,348	2.2285
Certified-advanced air bags	2,573	1,186	2.1695
	$\chi^2 = 0.3122$	P-Value = 0.5763	% Reduction = 2.65%
Sled-certified without advanced features	830	378	2.1958
Certified-advanced air bags	723	319	2.2665
	$\chi^2 = 0.1200$	P-Value = 0.7290	% Reduction = -3.22%
Sled-certified with advanced features	2,174	970	2.2412
Certified-advanced air bags	1,850	867	2.1338
	$\chi^2 = 0.7578$	P-Value = 0.3840	% Reduction = 4.79%

The overall result for certified-advanced air bags is a 2.65 percent reduction in frontal fatalities. However, this reduction is not statistically significant with $\chi^2 = 0.3122$ and the p-value = 0.5763. Individually looking at the transition to certified-advanced air bags from sled-certified with and without advanced features, there is a slight contrast in effectiveness. Without advanced features, the percentage reduction is negative, implying that vehicles equipped with certified-advanced air bags have a higher exposure to frontal fatalities than vehicles with sled-certified air bags without advanced features. However, the observed increase is just 3.22 percent and it is not statistically significant. Air bags transitioning from sled-certified with advanced features displayed similar results to the overall effectiveness, i.e., a positive but not statistically significant percentage reduction.

This next table now provides the same breakout but includes another layer by breaking down overall effectiveness by vehicle type. Vehicle type is broken down into passenger cars and light trucks and vans. LTVs include pickup trucks, SUVs, minivans, and full-sized vans.

Table 2: Overall Effect of Certified-Advanced Air Bags by Vehicle Type

Passenger Cars	Frontal Fatalities	Non-Occupant Fatalities	Frontal/Non-Occupant Risk Ratio
Sled-certified with or without advanced features	1,808	697	2.5940
Certified-advanced air bags	1,530	632	2.4209
	$\chi^2 = 1.1293$	P-Value = 0.2879	% Reduction = 6.67%
LTVs	**Frontal Fatalities**	**Non-Occupant Fatalities**	**Frontal/Non-Occupant Risk Ratio**
Sled-certified with or without advanced features	1,196	651	1.8372
Certified-advanced air bags	1,043	554	1.8827
	$\chi^2 = 0.1165$	P-Value = 0.7328	% Reduction = -2.48%

The result by vehicle type shows a slight contrast in effectiveness. Passenger cars showed a positive percentage reduction, while LTVs showed a small percentage increase in frontal fatalities. However, neither result was statistically significant.

Frontal Fatalities Relative to Non-Frontal Fatalities

An odds ratio was computed using frontal impacts as the treatment group and non-frontal impacts as the control group. Table 3 provides results for vehicles transitioning from sled-certified with and without advanced features to certified-advanced air bags individually and together. Table 3 is identical to Table 1, except non-frontal fatalities are substituted for non-occupant fatalities.

Table 3: Overall Effect of Certified-Advanced Air Bags (With Non-Frontal Control Group)

	Frontal Fatalities	Non-Frontal Fatalities	Frontal/Non-Frontal Risk Ratio
Sled-certified with or without advanced features	3,004	2,599	1.1558
Certified-advanced air bags	2,573	2,206	1.1664
	$\chi^2 = 0.0528$	P-Value = 0.8183	% Reduction = -0.91%

Sled-certified without advanced features	830	668	1.2425
Certified-advanced air bags	723	648	1.1157
	$\chi^2 = 2.0583$	P-Value = 0.1514	% Reduction = 10.2%
Sled-certified with advanced features	2,174	1,931	1.1258
Certified-advanced air bags	1,850	1,558	1.1874
	$\chi^2 = 1.3128$	P-Value = 0.2519	% Reduction = -5.47%

Similar to the overall results captured with non-occupant fatalities as the control group, none of the effectiveness percentages are statistically significant. The overall result for certified-advanced air bags is a 0.91 percent increase in frontal fatalities with $\chi^2 = 0.0528$ and the p-value = 0.8183. A difference between the two control groups are the percentage reductions for the transitions to certified-advanced air bags from sled-certified with and without advanced features. The percentage reductions with non-frontal fatalities as the control group are the opposite of the percentage reduction obtained with non-occupant fatalities as the control group. Without advanced features the result is a non-significant 10.2 percentage reduction, while with advanced features the result is a non-significant percentage increase of 5.47 percent.

This next table now provides the same breakout but now adds another layer by breaking down overall effectiveness by vehicle type.

Table 4: Overall Effect of Certified-Advanced Air Bags by Vehicle Type (With Non-Frontal Control Group)

Passenger Cars	Frontal Fatalities	Non-Frontal Fatalities	Frontal/Non-Frontal Risk Ratio
Sled-certified with or without advanced features	1,808	1,525	1.1856
Certified-advanced air bags	1,530	1,256	1.2182
	$\chi^2 = 0.2764$	P-Value = 0.5991	% Reduction = -2.75%
LTVs	**Frontal Fatalities**	**Non-Frontal Fatalities**	**Frontal/Non-Frontal Risk Ratio**
Sled-certified with or without advanced features	1,196	1,074	1.1136
Certified-advanced air bags	1,043	950	1.0979
	$\chi^2 = 0.0533$	P-Value = 0.8173	% Reduction = 1.41%

The result by vehicle type shows a slight contrast in effectiveness and is directionally opposite of results obtained with non-occupant fatalities as the control group. Passenger cars showed a

percentage increase of 2.75, while LTVs showed a 1.41 percent reduction. However, both results were not statistically significant.

Frontal Fatalities per Million Vehicle Registration Years

This analysis is different from the preceding analyses. As mentioned in the "Method for Supplementary Analysis," this analysis is based on FARS data and Polk's NVPP, which provides corresponding counts of registration years for vehicles selected for the study. This analysis does use all of the definitions and restrictions used in the previous analyses; however it adds one more restriction. The analysis will now exclude vehicles when the MY $\geq$ CY. NVPP states how many vehicles of model year X were registered on July 1 of calendar year Y. Early vehicles of the "next" model year (X = Y + 1) are entirely omitted in some years of NVPP, and even when included the count of vehicles registered on July 1 is a poor estimate of the registration years they accumulated. Strictly speaking, even for vehicles of the "current" model year (X = Y), the registration count for July 1 is not that accurate an estimate of the registration years accumulated by that MY in that CY, and therefore will be omitted from the analysis.

Table 5: Overall Frontal Fatalities per Million Vehicle Years Before and After Advanced 208-Compliant Certification

	Frontal Fatalities	Vehicle Years	Frontal Fatalities per Million Years
Sled-certified with or without advanced features	3,004	68,977,602	43.55
Certified-advanced air bags	2,424	57,959,450	41.82
	$\chi^2 = 2.1992$	P-Value = 0.1381	% Reduction = 3.97%

Table 5 measures the percent reduction in the overall fatality rates, in frontal crashes, per million registration years, following advanced 208-compliant certification. The fatality rate with certified-advanced air bags (41.82) is 3.97 percent lower than vehicles with sled-certified with and without advanced features (43.55). The 3.97 percent reduction is not statistically significant.

Pedestrian Versus Non-frontal Fatalities

There was a noticeable but slight difference between the two control groups when the comparison was made between sled certified air bags with and without advanced features. When comparing vehicles that made the transition to certified-advanced air bags from sled-certified without advanced features, there was a percentage increase when the control was pedestrian fatalities, but a reduction for non-frontal fatalities. The reverse occurs when comparing vehicles that make the transition to certified-advanced air bags from sled-certified with advanced features. This polarity between the two groups is also carried on when breaking down the overall fatality risk between vehicle types. For passenger cars, a reduction was noticed in comparison to pedestrian fatalities, but an increase in frontal fatalities was experienced in comparison to non-frontal fatalities. The vice versa occurs when examining the fatality rates of LTVs. Importantly, though, not a single one of the preceding analyses generated a statistically significant difference.

Intuitively, using non-frontal impact fatalities as a control group seems reasonable since frontal air bags are primarily designed for action in frontal crashes. However, this control group may provide some bias in the comparison. For example, changes in side air bags occurred at the same time as the transition to certified-advanced air bags and side impacts are included in non-frontal fatalities. These observations may yield a biased result due to changes in side air bags and not solely upon the transition to certified-advanced air bags. Therefore, all further analyses use non-occupant fatalities as the control group.

Effects of Certified-Advanced Air Bags on Drivers' Fatality Risk in Frontal Crashes

Drivers' Overall Fatality Risk

IIHS reported an increase rate of mortality for drivers of vehicles with certified-advanced air bags. Table 6 provides below the overall comparison for drivers of vehicles transitioning to certified-advanced air bags.

Table 6: Drivers - Effect of Certified-Advanced Air Bags

	Frontal Fatalities	Non-Occupant Fatalities	Frontal/Non-Occupant Risk Ratio
Sled-certified with or without advanced features	2,457	1,348	1.8227
Certified-advanced air bags	2,083	1,186	1.7563
	$\chi^2 = 0.5567$	P-Value = 0.4556	% Reduction = 3.64%
Sled-certified without advanced features	693	378	1.8333
Certified-advanced air bags	610	319	1.9122
	$\chi^2 = 0.2003$	P-Value = 0.6545	% Reduction = -4.30%
Sled-certified with advanced features	1,764	970	1.8186
Certified-advanced air bags	1,473	867	1.6990
	$\chi^2 = 1.3492$	P-Value = 0.2454	% Reduction = 6.58%

The results from the table actually show that the drivers' fatality risk decreases when transitioning to certified-advanced air bags. Overall, drivers' fatality risk is a 3.64-percent reduction with $\chi^2 = 0.5567$ and the p-value = 0.4556. IIHS stated that with the correction for vehicle age resulted in a 13 percent higher mortality rate for drivers of vehicles having certified-advanced air bags compared with vehicles having sled-certified air bags with advanced features. Comparing frontal fatalities to pedestrian fatalities for the vehicles' transitioning to certified-advanced air bags from sled-certified air bags with advanced features, a 6.58-percent reduction was observed for drivers' fatality risk.

The following table further breaks down drivers' fatality risk into subcategories of vehicle type, belt usage, age, gender, weight and height. The percentage reduction is only shown for the comparison between all vehicles transitioning to certified-advanced air bags, without separate breakout for sled-certified with or without advanced features.

Table 7: Driver Breakout: Percent Reduction in Fatality Risk for Certified-Advanced Air Bags Relative to Sled-Certified (With or Without Advanced Features)

	Percent Reduction	$\chi 2$
Vehicle Type		
Passenger Car	7.08	1.1945
LTV	-0.52	0.0049
Belt Use		
Not Belted	6.80	0.1423
Belted	-5.92	0.9204
Gender		
Male	6.62	1.1815
Female	-0.92	0.0126
Age		
13-29	8.96	1.0727
30-55	5.05	0.4591
56-69	-16.31	1.4406
70+	17.21	1.2905
Driver Height		
Up to 5'3"	-11.57	0.7769
5'4" to 6'	3.81	0.4819
Over 6'	2.11	0.0240
Driver Weight		
Up to 125 pounds	13.31	0.7042
126-199 pounds	0.37	0.0024
200 pounds and up	4.14	0.1389

Not a single percentage reduction shown is statistically significant; $\chi 2$ is always less than 3.84. The analyses do not show any subgroup of occupants or vehicles where CAC air bags are significantly more effective, or less effective than sled-certified air bags.

Drivers' Frontal Fatalities per Million Vehicle Registration Years

This analysis method compares drivers' fatality rates per million vehicle registration years immediately before versus after advanced FMVSS No. 208-compliant certification.

Table 8: Drivers' Frontal Fatalities per Million Vehicle Years Before and After Advanced 208-Compliant Certification

	Frontal Fatalities	Vehicle Years	Frontal Fatalities per Million Years
Sled-certified with or without advanced features	2,457	68,977,602	35.62
Certified-advanced air bags	1,964	57,959,450	33.89
	$\chi^2 = 2.7205$	P-Value = 0.0991	% Reduction = 4.87%

Table 8 measures the percent reduction in the drivers' fatality rates, in frontal crashes, per million registration years, following advanced FMVSS No. 208-compliant certification. The fatality rate with certified-advanced air bags (33.89) is 4.87 percent lower than in vehicles whose air bags were sled-certified with and or without advanced features (35.62). The 4.87 percent reduction is not statistically significant.

Effects of Certified-Advanced Air Bags on Right-Front Passengers' Fatality Risk in Frontal Crashes

RF Passengers' Overall Fatality Risk

As identical to the previous sections, this following table provides the overall fatality rate for the right-front passenger.

Table 9: RF Passengers - Effect of Certified-Advanced Air Bags

	Frontal Fatalities	Non-Occupant Fatalities	Frontal/Non-Occupant Risk Ratio
Sled-certified with or without advanced features	547	1,348	0.4058
Certified-advanced air bags	490	1,186	0.4132
	$\chi^2 = 0.0594$	P-Value = 0.8075	% Reduction = -1.82%
Sled-certified without advanced features	137	378	0.3624
Certified-advanced air bags	113	319	0.3542
	$\chi^2 = 0.0239$	P-Value = 0.8772	% Reduction = 2.26%
Sled-certified with advanced features	410	970	0.4227
Certified-advanced air bags	377	867	0.4348
	$\chi^2 = 0.1104$	P-Value = 0.7397	% Reduction = -2.88%

The overall result for certified-advanced air bags is a 1.82 percent increase in frontal fatalities. However, this percentage reduction is not statistically significant with $\chi^2 = 0.0594$ and the p-value = 0.8075. Individually looking at the transition to certified-advanced air bags from sled-certified with and without advanced features, there is a slight contrast in effectiveness. Without advanced features, a percentage reduction was observed. However, air bags transitioning from sled-certified with advanced features observed a percentage increase in fatality risk.

Child RF Passengers' Fatality Risk in Frontal Crashes

Frontal Fatalities per Billion Vehicle Registration Years

This analysis method compares the fatality rates per billion vehicle registration years of children riding in the front seat, before versus after advanced FMVSS 208-compliant certification. Table 10 shows the rate of fatalities in frontal crashes, per billion registration years, for child passengers up to12 years old riding in the right-front seat. The selection of make-models, ranges

of model years, ranges of calendar years, and totals of vehicle registration years are identical to the analyses in Tables 5 and 8 (i.e., they exclude cases with MY ≥ CY).

Table 10: Right-Front Seat Child Passengers up to12 Years Old, Frontal Fatalities per Billion Vehicle Years, Before and After Advanced 208-Compliant Certification

	Frontal Fatalities	Vehicle Years	Frontal Fatalities per Billion Years
Sled-certified with or without advanced features	15	68,977,602	217.55
Certified-advanced air bags	12	57,959,450	206.94
	$\chi^2 = 0.0166$	P-Value = 0.8973	% Reduction = 4.79%

Table 10 measures the percent reduction in the child RF passengers' fatality rates, in frontal crashes, per billion registration years, following advanced FMVSS No. 208-compliant certification. The fatality rate with certified-advanced air bags (206.94) is 4.79 percent lower than in vehicles with sled-certified with and without advanced features (217.55). The 4.79 percent reduction is not statistically significant.

Both rates are **much** lower than the 992.0 fatalities per billion miles in CY 1998-2004 with barrier-certified pre-1998 air bags.[12] Depowering, movement of child passengers to the back seat, and advanced features introduced in the years before CAC have all contributed to the dramatic reduction in fatality rates. Even though CAC air bags do not show a substantial additional improvement, at least not in this data, they confer two important safety benefits: (1) Even though NHTSA strongly recommends that all children sit in the back seats whenever possible, regardless of what type of air bag is present in the vehicle, this is not always possible; CAC air bags permit transporting a child in the front seat in an emergency situation when every back seat is occupied or a child needs constant supervision due to a medical condition. (2) CAC air bags have facilitated the gradual phase-out of manual on-off switches for passenger air bags in pickup trucks and other vehicles without a full back seat; unlike CAC air bags, the switches required human surveillance to assure that they were correctly set, depending on the age and size of the front passenger.

Review of Individual FARS Fatalities of Front Seat Child Passengers in Frontal Crashes

In FARS, a total of 28 fatalities in frontal crashes were recorded for a child up to 12 Years Old sitting in the right-front seat (the 27 in Table 10 plus one additional fatality excluded from that table because MY = CY): 15 fatalities were associated with a vehicle equipped with sled-certified air bags with or without advanced features, and the remaining 13 fatalities occurred in vehicles equipped with certified-advanced air bags. There are two reasons for concentrating on these cases and reviewing them individually: (1) To scan all 28 cases for fatalities possibly due to occupant contact with air bags in otherwise survivable crashes, similar to the SCI cases discussed later on. (2) To scan the 13 CAC cases for instances where the air bag deployed for a

[12] Kahane (2006), pp. 80-81.

relatively small child or did not deploy (despite the crash being fairly severe) for a larger child, possibly indicating issues with the design or the performance of the suppression algorithm.

However, when scanning FARS cases, it is important to keep in mind that even though FARS provides much information about the crash, (such as the number of vehicles and their makes and models and the number of occupants in each vehicle, their ages and seat positions), data elements such as the impact speed, detailed injury data, or the extent of vehicle intrusion or deformation are not reported. Other relatively complex data elements, such as the exact impact location and whether the air bag deployed are reported in FARS, but are not completely reliable. Specifically, the determination that the "primary" impact is frontal is complicated when there are multiple impacts, or the impact is oblique or on the front corner, or there is a subsequent rollover. Generally speaking, the review of FARS cases cannot identify which ones <u>are</u> like SCI; at best the review can identify what cases are almost certainly <u>not</u> like SCI cases. Similarly, because FARS does not report the weight of a child passenger, we can do no more than guess whether a deployment or non-deployment might have involved issues with the suppression algorithm.

The following table displays the age distribution of the fatalities. Twenty of the 28 fatalities are 8 or older, but nine are 7 or younger. The age distribution is more or less the same before and after CAC.

Table 11: Age Distribution of Front Seat Child Passengers Up to 12 Years Old, Frontal Fatalities

Age	Sled-certified with or without advanced features	Certified-advanced air bags
2	2	1
3	1	0
5	1	1
7	1	1
8	2	3
9	2	2
10	1	4
11	3	0
12	2	1
Total	15	13

The next two tables examine the right-front passenger's belt use and deployment status of the passenger air bag, according to FARS, in fatality cases in vehicles equipped with sled-certified with or without advanced features (Table 12) or certified-advanced air bags (Table 13).

Table 12: Seat Belt Usage and Air Bag Status of Front seat Child Passengers Up to 12 Years Old, Frontal Fatalities Equipped With Sled-Certified With or Without Advanced Features

Age	Seat Belt Status	RF Air Bag Deployment Status
2	Child safety seat used improperly	Not applicable
2	Child restraint system-forward facing	Deployed
3	Unrestrained	Deployed
5	Child safety seat	Not deployed
7	Unrestrained	Not deployed
8	Lap shoulder belt	Deployed multiple directions
8	Lap shoulder belt	Deployed
9	Unrestrained	Deployed
9	Unrestrained	Deployed
10	Unrestrained	Deployed
11	Lap shoulder belt	Deployed
11	Unrestrained	Deployed unknown location
11	Lap shoulder belt	Deployed
12	Unrestrained	Deployed unknown location
12	Unrestrained	Deployed combination

Table 13: Seat Belt Usage and Air Bag Status of Front seat Child Passengers Up to 12 Years Old, Frontal Fatalities equipped with Certified-Advanced Air Bags

Age	Seat Belt Status	RF Air Bag Deployment Status
2	Child safety seat	Deployed
5	Unrestrained	Not deployed
7	Unrestrained	Side air bag deployment
8	Lap shoulder belt	Deployed
8	Unrestrained	Deployed
8	Lap shoulder belt	Side air bag deployment
9	Unrestrained	Not deployed
9	Lap shoulder belt	Not deployed
10	Lap shoulder belt	Deployed
10	Unrestrained	Unknown direction of deployment
10	Lap shoulder belt	Unknown direction of deployment
10	Lap shoulder belt	Deployed
12	Unrestrained	Not deployed

Cases involving certified-advanced air bags are of particular interest if the air bag reportedly deployed for a small child (6 or younger) or did not deploy for a large child (11 or older), contrary to what would be expected given weight sensors and suppression. We note that even deployment for small children may occasionally be consistent with advanced air bag requirements if the vehicle is certified to the low-risk deployment option, just as suppression for an older child may occasionally be appropriate depending on the suppression threshold selected

by the manufacturer and the child's weight. For vehicles using the suppression option and front seat children of intermediate age (7 to 10, say) it is impossible to judge if the air bag "should have" deployed, because the weight of the child is not reported in FARS. It is also important to recognize that within the gray zone between the 6-year-old and 5th percentile female, manufacturers could choose a different deployment strategy for belted and unbelted occupants.

Out of the 28 fatalities, seven were restrained while eight were unrestrained in vehicles equipped with sled-certified with or without advanced features air bags, while with certified-advanced air bags, seven were restrained while the other six were unrestrained. One unrestrained case did capture interest, which was the unrestrained 12-year-old in a 2003 Chevrolet Avalanche 1500 equipped with certified-advanced air bags and the air bag did not deploy. The event for the 12-year-old shows that the initial and most damaged area occurred at the 1 o'clock position, which perhaps indicates an impact that had a strong lateral component or involved the corner of the vehicle; that may be the contributing factor to why the right-front passenger air bag did not deploy. The occupant's weight may also have been in the gray zone between the 6-year-old and 5th percentile female, in which case, manufacturers can choose a different deployment strategy for belted and unbelted occupants.

An interesting case involving sled-certified with or without advanced features was the 5-year-old restrained in a child safety seat in a 2003 Toyota Camry and where the air bag did not deploy. In this case, the 2003 Toyota Camry was the striking vehicle in a rear end collision. The driver of this vehicle was not a fatality, but the driver's air bag also did not deploy. This may be a sign that the collision was not of a great enough magnitude to initiate deployment of the air bag, but still sufficient to fatally injure the child right-front passenger.

Looking at the seven restrained cases in vehicles equipped with certified advanced air bags, there is one case that is the most interesting. This is the case of a 2-year-old in a child safety seat of a 2003 Chevrolet Silverado C1500 and the air bag deployed according to FARS. In this case three vehicles were involved with one being a Peterbilt heavy truck. Another specific of the case is that the driver of the vehicle with the child fatality was also killed. Thus, it does not resemble SCI cases of "otherwise survivable crashes." However, as for the 2-year-old, the available data supplied no additional information as to why the air bag deployed (if, in fact, it did).

Now it is important to examine the status of the driver of the vehicle with the child fatality to deem if the crash resembles SCI cases of "otherwise survivable crashes." Out of the remaining 6 restrained fatalities of vehicles equipped with certified-advanced air bags, 2 involved the drivers of the vehicles with the child fatality also being a fatality. These two cases involved a 10-year-olds with frontal air bag deployment and another 10-year-old with unknown direction of deployment. For vehicles equipped with sled-certified with or without advanced features, there were 6 cases, 4 restrained and 2 unrestrained where both the drivers and the child right-front passengers were fatalities. The 4 restrained cases involved an 8-year-old with multiple deployments, 2-year-old, 11-year-old and 8-year-old with frontal deployment. The two unrestrained cases involved a 7-year-old with no deployment and an 11-year-old with unknown deployment location.

In the remaining four restrained cases involving vehicles equipped certified-advanced air bags, one case involved an 8-year-old and side air bag deployment (but not in the frontal air bag). In this event, the vehicle was struck at the 1 o'clock position, which indicates that the collision may not have been a truly frontal collision, but more likely an oblique corner collision on the side where the right-front passenger was sitting. This next case involves a 9-year-old with frontal air bag deployment. In this case, the vehicle goes into a ditch and endures a subsequent rollover, which could have been the contributing factor to the child fatality.

The final two fatalities, an 8- and a 10-year-old, both with right-front air bag deployment, were positioned in vehicles with frontal damage in a front-to-side, right-angle collision. In both cases, the child was the only fatality in the vehicle. Thus, FARS does not provide evidence to rule out the possibility that these are relatively low-severity impacts, but it also does not provide evidence that they are of low severity. It is also important to understand that these fatalities and others of children of intermediate age (7 to 10) or older, reach a gray zone between the 6-year-old and 5th percentile female, where manufacturers could choose a different deployment strategy for belted and unbelted occupants. Since the data collected for FARS has a limitation (weight of passengers is not collected), and suppression for an older child may be appropriate depending on the suppression threshold selected by the manufacturer and the child's weight, the weight of these 7- to 12-years-olds may be in the ranges of either the air bag deploying or not deploying.

Supplementary Analyses for Child RF Passengers' Overall Fatality Risk

SCI fatalities for Front Seat Child Passengers

NHTSA's Special Crash Investigation) program identifies cases of fatalities due to occupant contact with air bags, as evidenced by detailed analysis of medical records and the vehicle interior, in otherwise survivable crashes, as evidenced by a delta-V estimated to be less than 40.2 km/h (25 mph). From CY 2004 to 2011 for MY 2002 to 2009, SCI has only one record of a child up to 12 years old sitting in the right-front seat with fatal injuries from air bags in otherwise survivable, low-to-moderate speed crashes (delta-V < 40.2 km/h [25 mph]). The vehicle associated with this child fatality was a MY 2003 Jeep Grand Cherokee. This vehicle's frontal air bags were sled-certified with advanced features, but not certified-advanced.

For certified-advanced air bags, SCI captured no child fatalities in the right-front seat that was due to occupant contact with the air bags. In actuality, there was only one record found with a child fatality in the right-front seat of a vehicle equipped with certified-advanced air bags, but the caveat is the frontal air bag did not deploy. This record did not come from SCI, but actually the Crashworthiness Data System. The vehicle of this record is a 2005 Chevrolet Silverado regular cab pickup, which is equipped with certified-advanced air bags. The child fatality in the right-front seat is not due to frontal air bag not deploying, but was the result of the child occupant being unrestrained and the events of the crash involving a rollover.

SCI investigations may be triggered soon after the crash if a police agency or other person notifies NHTSA that a crash of interest has occurred, or subsequently by a review of the FARS or CDS. The query results of the SCI database show signs that child fatalities in the right-front

seat may be declining now that vehicles are being equipped with certified-advanced air bags and that reporting to SCI may also have declined because the events have become so rare.[13]

CIREN Fatalities for Front Seat Child Passengers

NHTSA's Crash Injury Research Engineering Network program is an in-depth investigation into the 12 percent of crash injuries making up 77 percent of the Nation's economic crash burden. The CIREN process combines prospective data collection with multidisciplinary analysis of medical and engineering evidence to determine injury causation in every crash investigation conducted. Similar to previous analyses, cases were filtered for children up to age 12 occupying the right-front seat. For certified-advanced air bags, no fatalities or cases are included in the database. For sled-certified with or without advanced features, there were two cases after CY 2004 of two vehicles produced on or after MY 2002, a 2002 Nissan Altima and a 2005 Kia Sedona. Both cases resulted in deployment with no fatalities to the child right-front passenger.

Seat Occupancy by Children, Front Versus Back Seats

NHTSA recommends that children up to age 12 ride in the back seat if possible, not only to avoid harm from air bags, but also because it is the safest place in the vehicle. This analysis examines if there was any trend in children ages 0-12 years moving to the front seat from the back seat after the advent of certified-advanced air bags. Conceivably, some people might mistakenly believe that the suppression features of these air bags have eliminated all concerns about the safety of the front seat. NHTSA's State Data System can furnish an adequate number of cases of crash data that specify seating position, restraint usage, and age. Currently, SDS contains data from 33 States and is compiled from police-reported crashes in a State.

Out of the 33 States, the following 6 States were used in the analysis: Florida, Georgia, Wisconsin, New York, Michigan, and Washington. These 6 States were able to meet the critical parameters of providing VIN, model year, person type, and seat position information. The data is for CY 2004 - 2010, when vehicles with certified-advanced air bags were on the road.

[13] NHTSA. (2010). *Special Crash Investigations: First Generation Frontal Air Bags, A Model for Future Corrective Action.* Report No. DOT HS 811 261. Washington, DC: National Highway Traffic Safety Administration.

Table 14: Children up to Age 12 Seat Occupancy, Front Versus Back Seats by States

Florida	Front Seats	Back Seats	Front/Back Seats Ratio
Sled-certified with or without advanced features	1,124	6,414	0.1752
Certified-advanced air bags	1,002	5,710	0.1755
Georgia			
Sled-certified with or without advanced features	1,648	9,268	0.1778
Certified-advanced air bags	1,443	7,707	0.1872
Michigan			
Sled-certified with or without advanced features	173	776	0.2229
Certified-advanced air bags	136	679	0.2003
New York			
Sled-certified with or without advanced features	1,357	9,461	0.1434
Certified-advanced air bags	1,239	8,290	0.1495
Washington			
Sled-certified with or without advanced features	507	4,083	0.1242
Certified-advanced air bags	363	3560	0.1020
Wisconsin			
Sled-certified with or without advanced features	550	3,221	0.1708
Certified-advanced air bags	445	2,643	0.1684

The results from the 6 States show there is really no trend in children up to 12 now moving to the front seat from the back seat. The data actually shows that the ratio of children sitting in the front seat versus back seat is the same before and after vehicles were equipped with certified-advanced air bags.

Discussion

The contingency-table analysis of fatality rates yielded a positive effectiveness of 3 percent for the overall front seat occupants' fatality rate of vehicles equipped with certified-advanced air bags, but the reduction was not statistically significant. Drivers' fatality rates decreased by 4 percent, while right-front passengers' fatality rates increased by 2 percent for vehicles equipped with certified-advanced air bags. However, similarly, these estimates were not statistically significant.

The fatality rate, in frontal crashes per vehicle registration years also showed small reductions after vehicles were equipped with certified-advanced air bags – overall, for drivers, and for child right-front passengers up to 12 years old. Again, none of these changes were statistically significant. FARS identified 13 fatalities of child right-front passengers up to 12 years old in vehicles equipped with advanced air bags, but due to the limitation of data in FARS, the level of detail in these 13 entries is insufficient to determine if the deployment of the air bag or the performance of its certified-advanced features were factors in the fatalities. SCI identified no child fatalities in the right-front passenger seat of vehicles with certified-advanced air bags due to occupant contact with the air bags, as evidenced by a detailed analysis of medical records and the vehicle interior, in otherwise survivable crashes, as evidenced by a delta-V estimated to be less than 40.2 km/h (25 mph). CIREN also identified no child fatalities in the right-front passenger seat of vehicles with certified-advanced air bags. Finally, State data show that the advent of certified-advanced air bags did not result in a movement of child passengers from the back seat to the front seat.

In conclusion, these results do not corroborate the claims of an IIHS report based on early data that certified-advanced air bags result in a higher fatality risk to front seat occupants in frontal crashes compared to sled-certified air bags of the three model years before certified-advanced air bags. NHTSA believes certified-advanced air bags fully preserve the benefits of previous generations of air bags for average-size and larger adults, while they have essentially eliminated risk for child passengers or small adults – without requiring any intervention by the vehicle's occupants (such as remembering to correctly set the on-off switch for the passenger's air bag).

Appendix

Table of Makes and Models Included in the Analyses, Type of Air Bag Just Before CAC Certification, and Model Years Included in the Analyses

MAKE	MODEL	PRE-CAC CERTIFICATION	PRE-CAC	CAC
ACURA	TL	SLED ADVANCED	2004	2005
ACURA	TSX	SLED ADVANCED	2004-2005	2006-2007
AUDI	A4/S4 (SEDAN & SW)	SLED ADVANCED	2002-2004	2006-2008
AUDI	A4/S4 (CV)	SLED ADVANCED	2004-2006	2007-2009
AUDI	A8	SLED ADVANCED	2005	2006
AUDI	A8L	SLED ADVANCED	2004-2005	2006-2007
BMW	745i/750i/760i	SLED ADVANCED	2002-2004	2005-2007
BMW	745iL/750iL/760iL	SLED ADVANCED	2002-2004	2005-2007
BMW	X5	SLED ADVANCED	2005	2006
BMW	Z4	SLED ADVANCED	2003	2004
BUICK	RAINIER	SLED ADVANCED	2004	2005
BUICK	RENDEZVOUS	SLED ADVANCED	2002-2004	2005-2007
CADILLAC	CTS	SLED ADVANCED	2003-2004	2005-2006
CADILLAC	ESCALADE & EXT	SLED	2002	2003
CADILLAC	XLR	SLED ADVANCED	2004-2005	2006-2007
CADILLAC	SRX	SLED ADVANCED	2004-2006	2007-2009
CHEVROLET	MALIBU SEDAN	SLED ADVANCED	2004-2005	2006-2007
CHEVROLET	MALIBU WAGON	SLED ADVANCED	2004-2005	2006-2007
CHEVROLET	EXPRESS 1500	SLED ADVANCED	2004-2006	2007-2009
CHEVROLET	AVEO	SLED	2004-2005	2006-2007
CHEVROLET	COBALT	SLED ADVANCED	2005	2006
CHEVROLET	CORVETTE	SLED ADVANCED	2005	2006
CHEVROLET	IMPALA	SLED ADVANCED	2004-2005	2006-2007
CHEVROLET	MONTE CARLO	SLED ADVANCED	2004-2005	2006-2007
CHEVROLET	AVALANCHE 1500	SLED	2002	2003
CHEVROLET	COLORADO	SLED ADVANCED	2004-2005	2006-2007
CHEVROLET	SILVERADO 1500	SLED	2002	2003
CHEVROLET	TRAILBLAZER/EXT	SLED ADVANCED	2004	2005
CHRYSLER	PT CRUISER	SLED	2003-2005	2006-2008
CHRYSLER	PT CRUISER CV	SLED	2005	2006
CHRYSLER	PACIFICA	SLED ADVANCED	2004	2005
CHRYSLER	TOWN & COUNTRY SWB/LWB SnG	SLED ADVANCED	2003-2004	2006-2007

MAKE	MODEL	PRE-CAC CERTIFICATION	PRE-CAC	CAC
DODGE	VIPER	SLED ADVANCED	2005-2006	2008-2009
DODGE	CARAVAN	SLED ADVANCED	2004-2005	2006-2007
DODGE	GRAND CARAVAN	SLED ADVANCED	2002-2004	2005-2007
FORD	FOCUS	SLED ADVANCED	2002-2004	2005-2007
FORD	LTD/CROWN VICTORIA	SLED ADVANCED	2002-2004	2006-2008
FORD	TAURUS	SLED ADVANCED	2002-2003	2004-2005
FORD	ESCAPE	SLED	2002-2004	2005-2007
FORD	ESCAPE HYBRID	SLED ADVANCED	2006	2007
FORD	FREESTAR	SLED ADVANCED	2004	2005
GMC	SAVANA 1500	SLED ADVANCED	2004-2006	2007-2009
GMC	CANYON	SLED ADVANCED	2004-2005	2006-2007
GMC	ENVOY/XUV/XL	SLED ADVANCED	2004	2005
GMC	SIERRA 1500	SLED	2002	2003
HONDA	ACCORD 2 DR	SLED ADVANCED	2002-2003	2004-2005
HONDA	ACCORD 4 DR	SLED ADVANCED	2003	2004
HONDA	ACCORD HYBRID	SLED ADVANCED	2006	2007
HONDA	ODYSSEY	SLED ADVANCED	2002	2003
HONDA	ELEMENT	SLED ADVANCED	2006	2007
HONDA	RIDGELINE	SLED	2006	2007
HYUNDAI	ELANTRA	SLED	2002-2003	2005-2006
HYUNDAI	SANTA FE	SLED	2003-2004	2005-2006
HYUNDAI	TIBURON	SLED	2005-2006	2007-2008
INFINITI	Q45	SLED ADVANCED	2005	2006
INFINITI	G35	SLED ADVANCED	2003-2004	2005-2006
INFINITI	FX35/FX45	SLED ADVANCED	2003-2005	2006-2008
ISUZU	ASCENDER 5/7	SLED ADVANCED	2004	2005
JAGUAR	S-TYPE	SLED ADVANCED	2003-2004	2005-2006
JAGUAR	X-TYPE	SLED ADVANCED	2002-2003	2005-2006
JEEP	LIBERTY	SLED ADVANCED	2002-2003	2004-2005
KIA	AMANTI	SLED	2004	2005
KIA	SORENTO	SLED	2003-2004	2005-2006
LAND ROVER	RANGE ROVER	SLED ADVANCED	2004-2006	2007-2009
LEXUS	SC 430	SLED ADVANCED	2004-2006	2007-2009
LEXUS	LX 470	SLED ADVANCED	2004-2006	2007-2009
LINCOLN	TOWN CAR	SLED ADVANCED	2002-2004	2006-2008
MAZDA	6	SLED ADVANCED	2003-2004	2005-2006
MAZDA	RX-8	SLED ADVANCED	2004-2005	2006-2007

MAKE	MODEL	PRE-CAC CERTIFICATION	PRE-CAC	CAC
MAZDA	MPV	SLED	2002-2003	2004-2005
MAZDA	TRIBUTE	SLED	2002-2004	2005-2007
MAZDA	B PICKUP /ACAB-PLUS	SLED	2004-2006	2007-2009
MERCURY	GRAND MARQUIS	SLED ADVANCED	2002-2004	2006-2008
MERCURY	SABLE	SLED ADVANCED	2002-2003	2004-2005
MERCURY	MARINER HYBRID	SLED ADVANCED	2006	2007
MERCEDES	C	SLED ADVANCED	2002-2004	2005-2007
MERCEDES	E	SLED ADVANCED	2003-2004	2005-2006
MERCEDES	SLK	SLED ADVANCED	2005-2006	2007-2008
MERCEDES	SL	SLED ADVANCED	2004-2006	2007-2009
MERCEDES	CLK	SLED ADVANCED	2003-2004	2005-2006
MINI	COOPER	SLED ADVANCED	2002-2004	2006-2008
MITSUBISHI	LANCER	SLED	2004-2005	2006-2007
MITSUBISHI	ENDEAVOR	SLED	2004	2005
MITSUBISHI	OUTLANDER	SLED	2003-2004	2005-2006
NISSAN	MAXIMA	SLED ADVANCED	2004	2005
NISSAN	ALTIMA	SLED ADVANCED	2004	2006
NISSAN	MURANO	SLED ADVANCED	2004-2005	2006-2007
NISSAN	350Z	SLED ADVANCED	2005-2006	2007-2008
PONTIAC	G6	SLED ADVANCED	2005	2006
PONTIAC	GRAND PRIX	SLED ADVANCED	2004-2005	2006-2007
PONTIAC	GTO	SLED	2005	2006
SAAB	9-2X	SLED	2005	2006
SAAB	9-3	SLED ADVANCED	2003-2005	2006-2008
SAAB	9-5	SLED ADVANCED	2003-2005	2006-2008
SATURN	ION	SLED ADVANCED	2005	2007
SATURN	VUE	SLED ADVANCED	2004-2005	2006-2007
SUBARU	FORESTER	SLED ADVANCED	2003-2005	2006-2008
SUBARU	IMPREZA	SLED	2004-2005	2006-2007
SUZUKI	AERIO	SLED	2002-2004	2005-2007
SUZUKI	FORENZA	SLED	2004	2005
SUZUKI	GRAND VITARA XL-7	SLED	2002-2003	2004-2005
SUZUKI	VERONA	SLED	2004	2005
TOYOTA	4RUNNER	SLED ADVANCED	2004-2005	2006-2007
TOYOTA	CAMRY	SLED ADVANCED	2002-2003	2004-2005

MAKE	MODEL	PRE-CAC CERTIFICATION	PRE-CAC	CAC
TOYOTA	LAND CRUISER	SLED ADVANCED	2004-2006	2007-2009
TOYOTA	TACOMA	SLED	2005	2006
TOYOTA	SEQUOIA	SLED	2002-2004	2005-2007
TOYOTA	TUNDRA	SLED	2005	2006
TOYOTA	TUNDRA ACCESS CAB	SLED	2005	2006
TOYOTA	TUNDRA DOUBLE CAB	SLED	2004	2005
VOLKSWAGEN	NEW BEETLE	SLED ADVANCED	2002-2003	2004-2005
VOLKSWAGEN	PHAETON	SLED ADVANCED	2004	2005
VOLVO	S60	SLED ADVANCED	2005	2006
VOLVO	V70	SLED ADVANCED	2004	2005
VOLVO	S80	SLED ADVANCED	2005	2006
VOLVO	XC70	SLED ADVANCED	2003-2004	2005-2006
VOLVO	XC90	SLED ADVANCED	2003-2004	2005-2006

DOT HS 811 834
September 2013

U.S. Department
of Transportation
**National Highway
Traffic Safety
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9885-092413-v2