ANALYSIS OF THE CRASH EXPERIENCE OF VEHICLES EQUIPPED WITH ANTILOCK BRAKING SYSTEMS (ABS) -AN UPDATE

Ellen Hertz
Judith Hilton
Delmas Maxwell Johnson
National Highway Traffic Safety Administration
United States
Paper Number 98-S2-O-07

ABSTRACT

This paper updates the findings from initial analyses of the crash experiences of passenger cars (PCs) and light trucks and vans (LTVs) equipped with antilock braking systems (ABS). As before, separate analyses were conducted for PCs and LTVs, for each type of ABS system (rear and all wheel), for each of several crash types and each type of road surface (favorable and unfavorable). The present analysis also considers crashes involving pedestrians, in addition to the four crash types previously considered. The findings for passenger cars in fatal crashes for this study are very similar to the earlier results, i.e, for non-fatal crashes the benefits in avoiding frontal crashes remain about the same. Side impacts and run-off-road crashes on unfavorable surfaces, went from a predicted increase in the earlier study to non-significance in these findings. In addition, there are decreases predicted for crashes involving pedestrians.

INTRODUCTION

Section 2507 of the Highway Safety Act of 1991 directed the National Highway Traffic Safety Administration (NHTSA) to initiate rulemaking to consider the need for any additional brake performance standards, including ABS, for all passenger vehicles, i.e., PCs and LTVs weighing less than 10,000 pounds. Meanwhile, automobile manufacturers have offered ABS to consumers either as a standard feature or as an option on millions of PCs and LTVs since 1985.

The objective of ABS is to automatically modulate braking pressure to prevent the vehicle's wheels from locking during braking. Two types of ABS systems are presently available: All wheel (AWAL) and rear wheel (RWAL). At the time of the earlier analysis, RWAL was much more prevalent in the on-road LTV fleet but AWAL is now becoming more available for LTVs. All PCs are equipped with AWAL and, therefore, only AWAL ABS was considered for PCs.

The focus of this study was to update earlier estimates of the impact of ABS using similar methods. As before, the impact of ABS on specific types of crashes considered to be "ABS relevant" was studied by examining the change in the proportion of crashes in which ABS had the potential to prevent the crash, assuming that the presence or absence of ABS does not affect the occurrence of nonrelevant crashes.

DATA

Data from NHTSA's Fatality Analysis Reporting System (FARS) were used to analyze the crash experience of ABS-equipped and non-ABS-equipped vehicles in both the PC and LTV analyses. FARS, begun in 1975, contains a census of the most severe traffic crashes, i.e., those resulting in a fatality, occurring in the United States each year. FARS data for calendar years 1995-96 were used in the analyses. The earlier analysis used FARS data from 1989-93.

For both the PC and the LTV analyses, state crash files from Florida, Maryland, Missouri, and Pennsylvania for the period 1995-96 were also used. These states were chosen for study because each, for the period shown, recorded the vehicle identification number (VIN) for vehicles involved in crashes of all severities. The VIN was needed in order to identify specific makes and models of vehicles equipped with ABS and to identify comparable non-ABS equipped vehicles. The earlier analysis used state data for the period 1989-93.

For both the PC and LTV analyses, five types of crashes were identified as "ABS-relevant", i.e., crashes for which it was assumed that ABS would be beneficial in avoiding the crash and/or ameliorating the outcome of the crash. The four "ABS-relevant" crash types identified in the original study were: (1) rollovers, (2) side impacts with parked vehicles or fixed objects, (3) frontal impacts with parked vehicles or fixed objects, and (4) frontal impacts with another motor vehicle in transport. In the present update, pedestrian crashes, were added. Crash types (1) and (2) typically involve driver loss of control. For these crash types, ABS is expected to increase the directional stability of the vehicle, allowing the driver to maintain greater control and remain on the roadway. Crash types (3) and (4), along with crash type (5), pedestrian crashes, typically involve driver loss of control or the presumption that the driver did not apply the brakes or was not able to stop in time. Both analyses examined the experiences for ABS and non-ABS-equipped vehicles in the ABS-relevant crash types, compared to a control group of crashes that were assumed to be unaffected by the presence of ABS. The control group consisted of crashes in which vehicles were struck while standing still or starting out after having been parked. In addition, the ABS-relevant crashes and control crashes were further classified based upon whether or not the crash occurred under "favorable" or "unfavorable" road conditions. Road surfaces that were paved, free of debris, and dry were considered "favorable." Road surfaces that were wet, snowy, icy, unpaved, or composed of gravel were considered "unfavorable."

ANALYSIS

The basic approach was to study the change in the proportion of ABS-relevant crashes for ABS-equipped vehicles compared to non-ABS-equipped vehicles. Since the presence or absence of ABS could not be expected to be the only important factor in the crash, the analysis technique used must control for factors related to the driver, environment, or other crash characteristics.

Logistic regression, as described in Hosmer and Lemeshow, was chosen as the analytical method. This technique has been successfully used in other NHTSA studies. To accurately estimate the impact of ABS, variables were included in the logistic regression to control for those factors, other than ABS, which could influence the proportion of ABS-relevant crashes. For example, if ABS-equipped pickup trucks are more likely to be driven by younger males than by other segments of the driving population, then driver and vehicle characteristics could confound estimating the impact of ABS. To address this issue, variables representing the age and sex of the driver, whether or not the crash occurred on a curved road segment, whether the crash occurred in a rural setting or an urban setting, and the age of the vehicle were included in the logistic regression models. Using the state and FARS data, for favorable or unfavorable surfaces, for each type of ABS (AWAL or RWAL), for the four ABS-relevant crash types, a logistic regression model was estimated:

$$\text{LOGIT (P) = AGE YOUNG MALE CURVED ABS RURAL}^{*}\text{ VEH-AGE} \qquad (1^{**}.)$$

where the data modeled include the particular ABS crash type response being analyzed and control crashes, P is the probability of an ABS-relevant response, AGE is the age of the driver, YOUNG is an indicator variable with the value 1 if the driver is under 25 years of age and 0 otherwise, MALE is an indicator variable representing the driver's sex, CURVED is a variable indicating whether or not the crash occurred on a curved or straight road segment, RURAL is a variable indicating whether or not the crash occurred in a rural or urban area, and VEH-AGE represents the age of the crash-involved vehicle.

Each of these models was run with a stepwise procedure that retained only ABS and those variables that were statistically significant. The final model results yielded estimates of the ABS coefficients (and their standard errors) for each database (FARS and the various state files), crash type, ABS system type, road surface type (favorable or unfavorable), for PCs and for LTVs. Since each coefficient represents the change in the log odds ratio of an ABS-relevant crash to an ABS-nonrelevant crash in the presence of an ABS-equipped vehicle, a negative coefficient indicates a reduction in crashes associated with the presence of ABS.

While crash reporting thresholds may differ somewhat from state to state, it appears reasonable to assume the effects of ABS should not differ dramatically. The results from the final models appeared to support this assumption. Therefore, the ABS coefficients for each state were statistically combined to form single estimates of the common log odds ratio for similar levels of ABS system type, crash type and road surface type, using the statistical methods described in Fleiss. These coefficients were translated into the percentage change in the expected number of relevant crashes using:

---

*RURAL was not recorded in the Missouri data. A variable indicating whether or not the crash occurred on a road with a 55 MPH or greater speed limit was substituted.

**For LTVs, a variable VAN, indicating if the vehicle was a van was also included in the model.

Expected percentage change =
100*[exp(ABS coefficient) -1] (2.)

Replacing the (ABS coefficient) in the above equation with (ABS coefficient $\pm$ 1.96*(standard error of the ABS coefficient)) yields estimates of the 95% confidence limits for the expected percentage change in relevant crashes. Tables 1., 2., and 3. present a summary of the statistically significant (at the p = 0.05 level) effects of ABS for PCs, AWAL LTVs, and RWAL LTVs, respectively. In each Table, the crash types Roll = rollover crashes, Side = Side impact crashes with parked vehicles or fixed objects, Front = Frontal impact crashes with another motor vehicle in transport, Ror = Run-off-road frontal impact crashes with parked vehicles or fixed objects and Ped = Pedestrian crashes; crash severity All = All severities and Fatal = fatal crashes only. For each table, 95% CL represents the 95% confidence limit values for the percentage change shown.

Table 1.
Summary of Statistically Significant Effects of ABS for Passenger Cars

Crash Severity	Crash Type	Road Type	% Change	95% CL
All	Roll	Fav	-17	-25 to -8
All	Ror	Fav	-13	-17 to -9
All	Side	Fav	+7	+1 to+14
All	Front	Unfav	- 42	-45 to -39
All	Front	Fav	- 18	-20 to -16
All	Ped	Unfav	-30	-35 to -24
All	Ped	Fav	-10	-14 to -7
Fatal	Roll	Fav	+51	+12 to+104
Fatal	Side	Unfav	+69	+5 to +174
Fatal	Side	Fav	+61	+19 to+117
Fatal	Front	Unfav	-40	-59 to -13
Fatal	Ped	Unfav	-38	-60 to -4

Table 2.
Summary of Statistically Significant Effects of ABS for AWAL-equipped Light Trucks and Vans

Crash Severity	Crash Type	Road Type	% Change	95% CL
All	Roll	Fav	-40	-54 to -40
All	Roll	Unfav	-43	-60 to -20
All	Ror	Unfav	-33	-47 to -17
All	Ror	Fav	-24	-35 to -12
All	Side	Unfav	-35	-54 to -8
All	Front	Unfav	-38	-46 to -29
All	Front	Fav	-14	-20 to -8
Fatal	Roll	Fav	+97	+34 to+190
Fatal	Roll	Unfav	+125	+10 to+358
Fatal	Side	Fav	+111	+17 to+281

Table 3.
Summary of Statistically Significant Effects of ABS for RWAL-equipped Light Trucks and Vans

Crash Severity	Crash Type	Road Type	% Change	95% CL
All	Roll	Unfav	-39	-48 to -28
All	Roll	Fav	-42	-48 to -34
All	Ror	Fav	-10	-17 to -3
All	Side	Unfav	-30	-40 to -18
All	Side	Fav	-13	-22 to -2
All	Front	Unfav	-10	-16 to -4
Fatal	Roll	Unfav	+89	+3 to+246
Fatal	Ror	Fav	-28	-44 to -7

CONCLUSIONS

The findings for passenger cars in fatal crashes for this study are very similar to the earlier results. For passenger cars in non-fatal crashes the benefits in avoiding frontal crashes remain about the same. Side impacts and run-off-road crashes on unfavorable surfaces, went from a predicted increase in the earlier study to non-significance in these findings. In addition, there are decreases predicted for crashes involving pedestrians.

For light trucks and vans, the two types of ABS, i.e., AWAL and RWAL, were analyzed separately. No significant predicted changes in fatal crashes had been found for AWAL systems in the earlier study, while the current analysis shows some predicted increases in rollovers and side impacts (both crash types associated with loss of control). In non-fatal crashes with AWAL, frontals on good surfaces went from an increase to a decrease and run-off-road crashes went from non-significance to a decrease. For LTVs with RWAL, the most dramatic change is that both fatal and nonfatal frontal crashes on favorable and unfavorable road conditions no longer show an increase as was the case in the earlier study.

These results surely raise as many questions as they answer. The overall impact of ABS for total crashes and fatalities, i.e., across all crash types, was not estimated in this study. Meanwhile, it has been hypothesized that the apparent increase in loss of control type crashes, i.e., rollovers and side impact crashes, results from successful deliberate attempts to steer off the road in order to avoid worse targets (most notably, perhaps, pedestrians) that now become possible because the wheels do not lock up. Some of the improved predictions for ABS, especially regarding non-fatal crashes in which the driver may be under less pressure, could possibly be due to increased skill on the part of motorists in using ABS. Also, the systems themselves may have been improved. Further analysis is planned which will take into account, where possible, the generation of the ABS and the driver's amount of experience with ABS. Meanwhile, NHTSA urges drivers to gain an in-depth understanding of the operation of their ABS-equipped vehicles to utilize the safety potential of ABS.

REFERENCES

Fleiss, Joseph, "Statistical Methods for Rates and Proportions". John Wiley and Sons, 1981.

Hertz, Ellen; Hilton, Judith; and Johnson, Delmas Maxwell, "An Analysis of the Crash Experience of Light Trucks and Vans Equipped with Antilock Braking Systems". U.S. Department of Transportation, NHTSA, DOT HS 808 278, May 1995.

Hertz, Ellen; Hilton, Judith; and Johnson, Delmas Maxwell, "An Analysis of the Crash Experience of Passenger Cars Equipped with Antilock Braking Systems". U.S. Department of Transportation, NHTSA, DOT HS 808 279, May 1995.

Hertz, Ellen; Hilton, Judith; and Johnson, Delmas Maxwell, "Analysis of the Crash Experience of Passenger Vehicles Equipped with Antilock Braking Systems". ESV Paper Number 96-S9-O-03, May 1996.

Hosmer, D.; Lemeshow, S., "Applied Logistic Regression". John Wiley and Sons, 1989.

Kahane, Charles J, "Preliminary Evaluation of the Effectiveness of Rear-Wheel Antilock Brake Systems for Light Trucks". U.S. Department of Transportation, NHTSA, December 1993.