An Example of the Crash Protection Provided by a Driver Airbag in an Offset Frontal Crash Test

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ABSTRACT

A comparison of two severe frontal offset crash tests illustrated the advantages of crash protection provided by a driver airbag. Two equivalent model passenger vans were crash tested into a fixed deformable barrier at 40 mi/h (64.4 km/h) with a 40 percent overlap on the driver side. In one van, the driver airbag was disabled. A comparison of the injury measures recorded from the dummies positioned in the driver seats indicated that while both crashes presented situations that would likely result in significant injuries, a human driver in the van with the disabled airbag certainly would have suffered serious injuries and might even have been killed. Although differences in the belt systems contributed to somewhat different occupant kinematics, the potential for airbags to prevent life-threatening injuries to the head and neck is clear.

INTRODUCTION

In response to growing concerns about injuries and deaths caused by airbags, the federal government has proposed a rule that would allow dealers and motor vehicle repair shops to deactivate airbags after the vehicles' owners have been fully informed about the risks and benefits of airbags. As a result of intense media coverage on the injuries and fatalities, some people have lost sight of the beneficial crash protection provided by airbags and are seriously considering deactivating them. The Insurance Institute for Highway Safety has conducted a pair of crash tests that illustrate the additional crash protection provided to belted drivers by airbags in severe frontal crashes.

METHODS

Two high-speed crash tests were conducted using a popular passenger van model, the Toyota Previa. Both tests were 40 mi/h (64.4 km/h), frontal offset crashes against a fixed deformable barrier with 40 percent of the vehicle's width aligned with the impact barrier. Vehicle preparation and testing protocol are described in *Crashworthiness Evaluation, Offset Barrier Crash Test Protocol (Version III).* The first test was conducted using a 1996 Toyota Previa with driver and passenger front airbags. The second test was conducted using a 1992 Toyota Previa with the driver airbag disabled. Test mass, actual impact speed, and actual overlap for each vehicle are shown in Table 1.

Table 1
Test Conditions

	1996 Toyota Previa (airbag) Test	1992 Toyota Previa (no airbag) Test
Vehicle test mass (kg)	1,874	1,897
Actual impact speed (km/h)	64.3	63.8
Actual overlap at impact (percent)	39	40

For both vehicle tests, a Hybrid III dummy, representing the 50th percentile adult male, was positioned in the driver seat with the lap/shoulder belt fastened. The dummy was equipped with sensors to monitor the forces acting on its head, neck (at the connection between its head and neck), chest, and legs. Deformation of the dummy's chest was also recorded. High-speed films of both crash tests were made so the dummy's movements could be studied in slow motion.

Acceleration of the test vehicles was measured by a triaxial arrangement of accelerometers located on the vehicle centerline near its precrash center of gravity. In addition, precrash and postcrash

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measurements were made across the bumpers and in the interiors of both vehicles to characterize the deformation resulting from the crash forces.

RESULTS

Vehicle comparisons: Figure 1 illustrates the crash damage experienced by the two vehicles. The magnitude of the front-end crush measured along the bumper of both vehicles was similar, except that the extreme left end of the 1996 model bumper was pushed further rearward than the same point on the 1992 model. The shapes of bumper deformation also were similar, but the front end of the 1996 model was bent more to the left. Measures of occupant compartment deformation were similar for the two vehicles (Table 2). The peak and duration of the measured acceleration pulses also were similar (Figure 2).

Figure 1
Front-End Crush Contour at Bumper —
1996 (airbag) and 1992 (no airbag) Toyota Previas

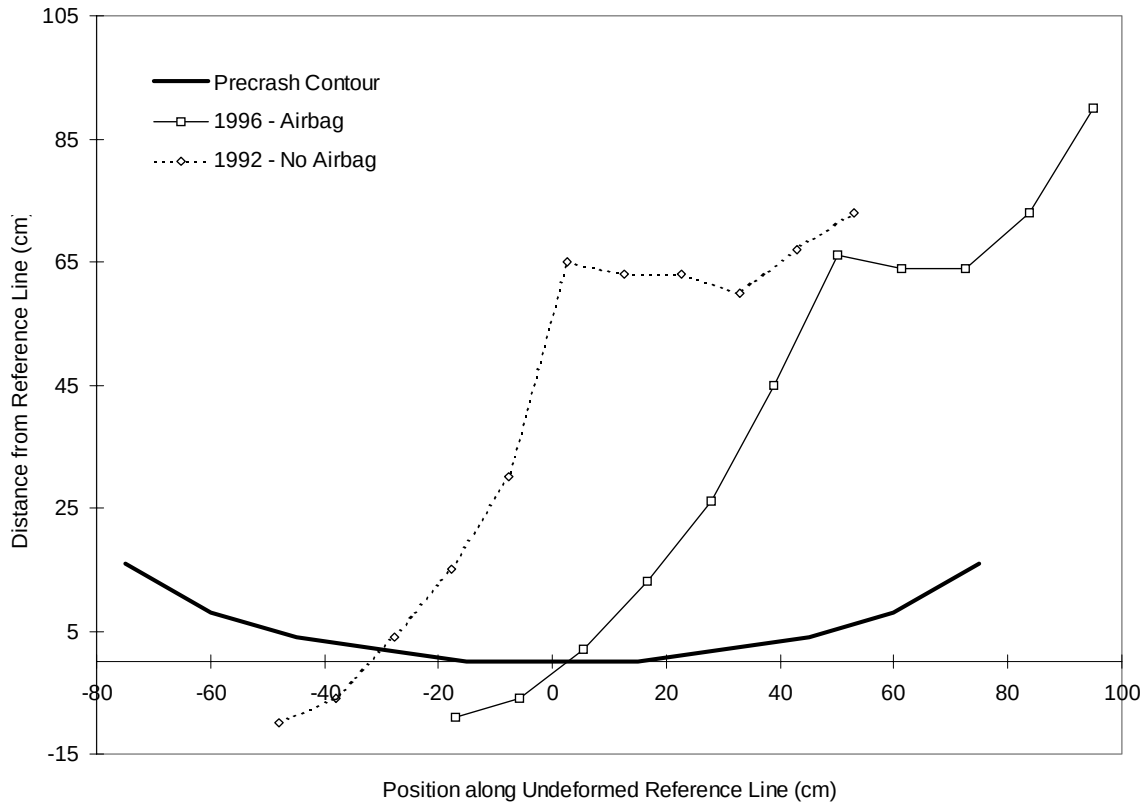
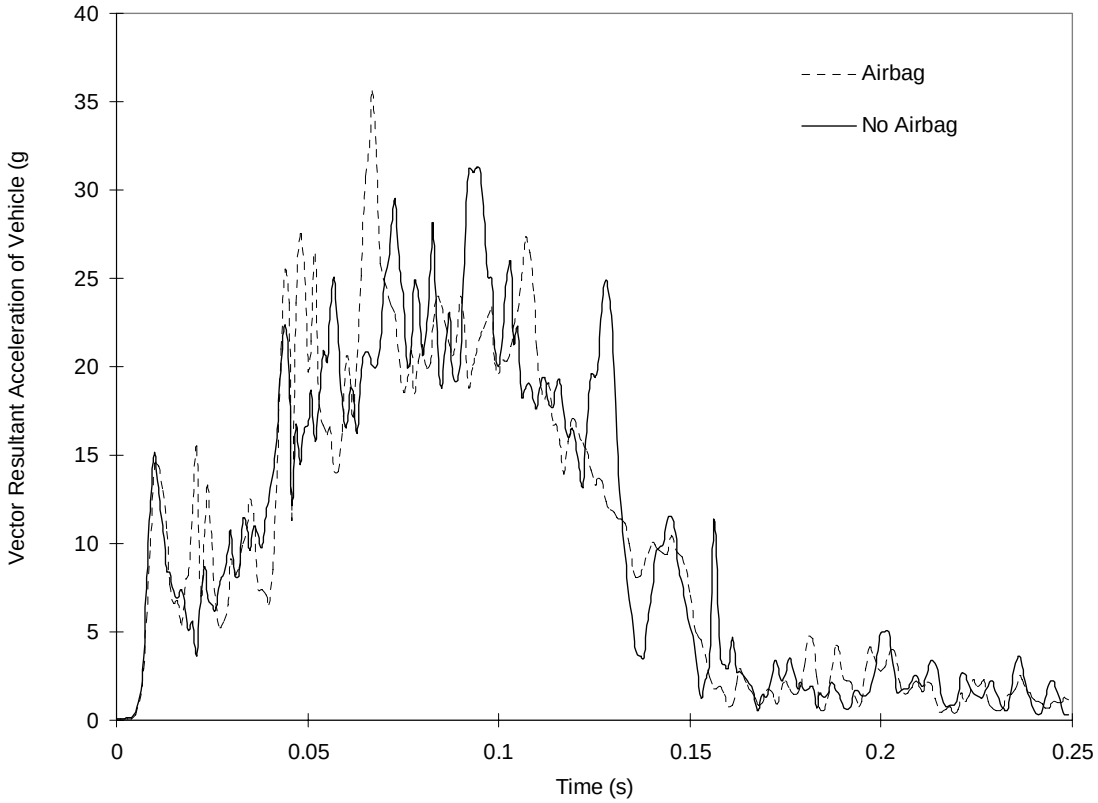


Table 2
Difference Between Precrash and Postcrash Interior Measurements (cm) —
1996 (airbag) and 1992 (no airbag) Toyota Previas

	Longitudinal		Lateral		Vertical		Resultant	
Measurement Location	**1996**	**1992**	**1996**	**1992**	**1996**	**1992**	**1996**	**1992**
Door opening	-3	-10	--	--	--	--	--	--
Left instrument panel	-8	-14	-5	-4	5	4	11	15
Right instrument panel	-12	-15	-3	-3	15	10	19	18
Steering column	-8	-14	6	1	17	12	20	19
Brake pedal	-22	-23	-10	-6	12	10	27	25
Left toepan	-20	-25	-15	-11	5	5	25	28
Center toepan	-21	-25	-13	-11	7	5	26	28
Right toepan	-24	-22	-11	-8	11	7	29	25
Footrest	-17	-18	-14	-12	3	3	22	22

Figure 2
Vehicle Acceleration —
1996 (airbag) and 1992 (no airbag) Toyota Previas



Restraint systems and dummy kinematics: The lap belt for the 1996 model was equipped with a force-limiting stitching pattern, which ripped during the crash, lengthening the belt loop 36 cm. In addition, 14 cm of webbing was pulled from the retractor during the crash. As the vehicle impacted the barrier, the high-speed films indicated the dummy slid forward on the driver seat until it contacted the fully inflated airbag. The dummy's head continued to move forward into the airbag, contacting the steering wheel underneath. The dummy's head then slid down across the airbag, contacting the steering wheel a second time as the dummy leaned backward. The dummy returned to the driver seat, lying back on the seat cushion with the lap belt resting up over its abdomen.

The lap belt for the 1992 model was not equipped with a force-limiting stitching pattern. The amount of webbing spool-out from the shoulder belt retractor could not be determined because the measurement device was damaged during the crash. The high-speed films indicated the dummy did not slide as far forward on the seat as in the 1996 model test (Figure 3). Instead, the dummy's torso leaned forward until its head contacted the hub of the intruding steering column. During rebound, the dummy's head contacted the B-pillar, and the dummy returned upright in the driver's seat.

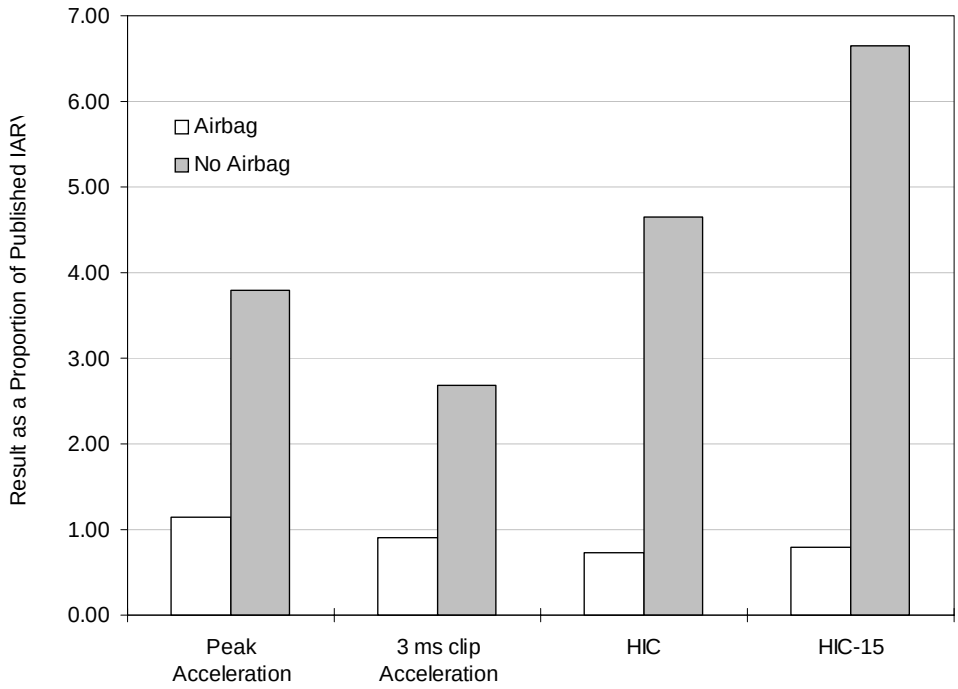
Figure 3
Dummies at Maximum Forward Excursion with and without Airbags

Injury measures: The maximum head injury measurements are summarized in Table 3 and Figure 4. Despite contacting the steering wheel through the airbag, all measures recorded during the 1996 model test, with the exception of the maximum resultant head acceleration, were well below published injury assessment reference values (IARV) (Backaitis and Mertz, 1994). For the 1992 model test, the dummy's head contact against the unprotected steering wheel hub produced injury measures that greatly exceeded published IARV.

Table 3
Head Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas

		Result	
Measure	**Published IARV**	**1996**	**1992**
Vector resultant acceleration (g)	80	91	304
Vector resultant acceleration - 3 ms clip (g)	80	72	214
Head injury criterion (HIC)	1000	733	4651
Head injury criterion - 15 ms interval (HIC-15)	700	552	4651

Figure 4
Head Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas

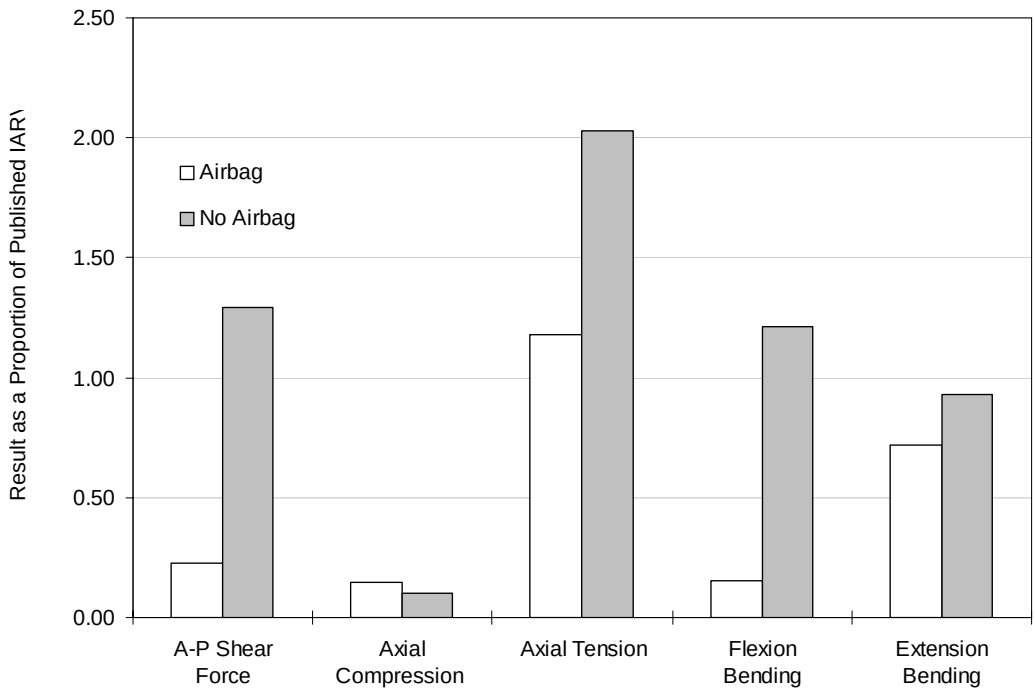


The maximum neck injury measurements are summarized in Table 4 and Figure 5. For the 1996 model test, the recorded neck tension forces exceeded the published IARV when the head contacted the steering wheel through the airbag the second time. For the 1992 model test, the neck tension force greatly exceeded the published IARV. Both the maximum recorded neck shear force and maximum neck flexion bending moment, which was recorded during the time when the dummy's head was in contact with the steering wheel, also were greater than the associated IARV.

Table 4
Neck Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas

		Result	
Measure	**Published IARV**	**1996**	**1992**
Anterior-posterior shear force (kN)	± 3.1	-0.7	-4.0
Axial compression force (kN)	4.0	0.6	0.4
Axial tension force (kN)	3.3	3.9	6.7
Flexion bending moment (Nm)	190	29	230
Extension bending moment (Nm)	57	41	53

Figure 5
Neck Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas

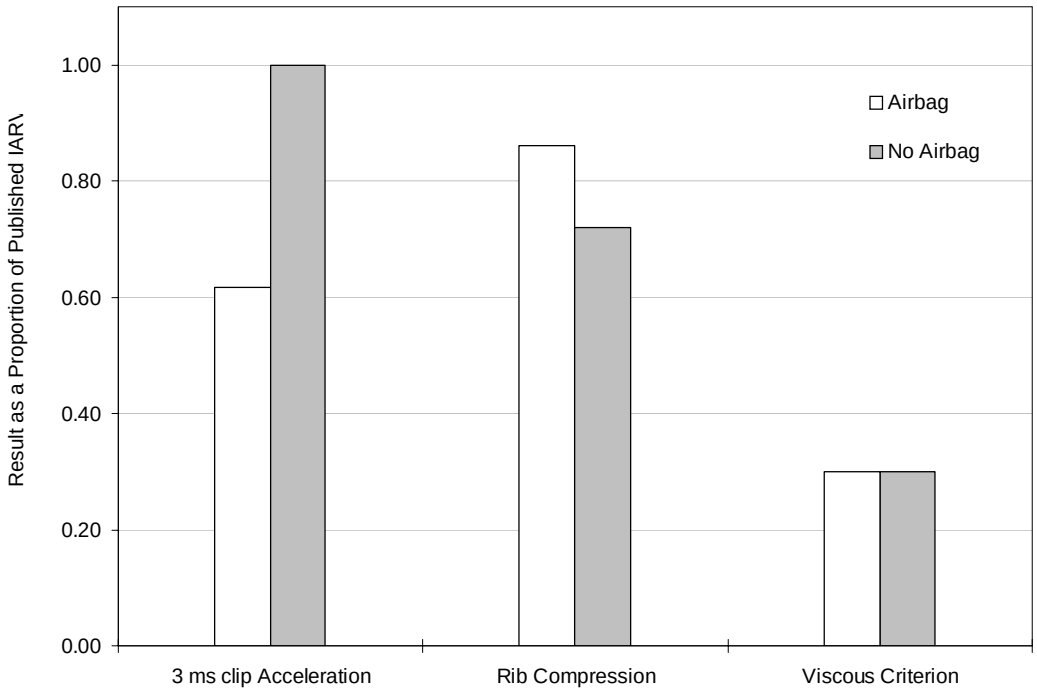


The maximum chest injury measurements are summarized in Table 5 and Figure 6. Only the spine acceleration recorded during the 1992 model test was near published IARV.

Table 5
Chest Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas

		Result	
Measure	**Published IARV**	**1996**	**1992**
Vector resultant spine acceleration - 3 ms clip (g)	60	37	60
Rib compression (mm)	50	43	36
Viscous criterion (m/s)	1.0	0.3	0.3

Figure 6
Chest Injury Measurements —
1996 (airbag) and 1992 (no airbag) Toyota Previas



DISCUSSION

Both the 1996 and 1992 model crash tests were severe and characterized by massive deformation of the occupant compartment and gross movement of the steering column. Almost certainly, a human occupant of either van in these tests would have suffered serious injury. However, there was a clear difference in the likelihood of survivability for the two drivers. Although the dummy in the 1996 van experienced high neck forces and struck the steering wheel through the airbag, the dummy in the 1992 van without the airbag fared much worse.

The HIC (4651) recorded during the 1992 model test is off the scale of an injury risk analysis conducted using existing head impact data (Prasad and Mertz, 1985). Such measures indicate the certainty of a life-threatening skull fracture or brain injury. In contrast, the HIC (733) recorded during the 1996 model test represents less than a 10 percent risk of life-threatening skull fracture or brain injury. The IARV for neck injury measures are intended to represent levels below which significant injuries (defined as Abbreviated Injury Scale level 3 and greater) are unlikely. The neck tension force recorded during the 1992 model test was more than twice the published IARV, suggesting that some significant neck injury would be expected. The maximum tension force recorded during the 1996 model test was only somewhat higher than the IARV.

Results from the U.S. Government's New Car Assessment Program (NCAP), which is based on a 35 mi/h (56 km/h) full width crash into a rigid barrier, also show the efficacy of driver airbags. Two Toyota Previa models were tested by NCAP: the 1991 non-airbag-equipped model and the 1994 dual airbag-equipped model. Table 6 shows a summary of the NCAP results for the two Toyota Previa crash tests.

Table 6
NCAP Results —
1991 (no airbags) and 1994 (dual airbags) Toyota Previas

	Results	
Measure	**1991**	**1994**
Driver		
HIC	1434	401
Chest acceleration - 3 ms clip (g)	66	58
Passenger		
HIC	790	532
Chest acceleration - 3 ms clip (g)	47	60

REFERENCES

Association for the Advancement of Automotive Medicine. 1990. *The Abbreviated Injury Scale, 1990 Revision*. Des Plaines, Ill: Association for the Advancement of Automotive Medicine.

Backaitis, S.H. and Mertz, H.J. (Eds.). 1994. *Hybrid III: The First Human-Like Crash Test Dummy*. Warrendale, PA: Society of Automotive Engineers.

Prasad, P. and Mertz, H.J. 1985. *The Position of the United States Delegation to the ISO Working Group 6 on the Use of HIC in the Automotive Environment (SAE 851246).* Warrendale, PA: Society of Automotive Engineers.

Insurance Institute for Highway Safety. 1996. *Crashworthiness Evaluation, Offset Barrier Crash Test Protocol (Version III).* Arlington, VA: Insurance Institute for Highway Safety

Insurance Institute for Highway Safety. 1996. *Crashworthiness Evaluation, 1996 Toyota Previa (CF96022).* Arlington, VA: Insurance Institute for Highway Safety

Insurance Institute for Highway Safety. 1997. *Offset Test of Vehicle with Disabled Airbag, 1992 Toyota Previa (CF96030).* Arlington, VA: Insurance Institute for Highway Safety