

Air Bag and Belt Restraint Performance in Frontal Crashes - Real World and Test Experience



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U.S. Department of Transportation

Presentation Overview

- Real World Crash Investigations
 - Children Fatally Injured by Air Bags
 - Sled-Certified Air Bag Restraint Performance in Moderate to Severe Crashes
- Laboratory Testing of Sled-Certified Vehicles
 - Low-Risk Deployment (OOP) Air Bag Testing
 - Frontal Crash Testing

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Nomenclature



- **FMVSS 208 – Rulemaking Summary**
 - **“Sled Certified” or “Redesigned” Air Bags are from vehicles that have certified to the March 1997, FMVSS 208 – Optional Sled Test Rulemaking.**
 - **“Advanced” Air Bags are from vehicles that have certified to the May 2000 – Advanced Air Bag Final Rule**

SCI and Air Bag Crashes



- The **Special Crash Investigations** (SCI) program is a component of the the National Center for Statistics and Analysis (NCSA) in the National Highway Traffic Safety Administration (NHTSA)
- SCI researchers perform special, intensive investigations of crashes selected for high interest
- Airbag-related fatal and serious injury cases are of particularly high interest

SCI and Air Bag Crashes



- **Cases of interest** located through:
 - Fatality Analysis Reporting System (FARS)
 - National Automotive Sampling System (NASS)
 - Other DOT and NHTSA research components, regional offices, and hotlines
 - Police and fire/rescue personnel
 - Auto manufacturers
- SCI files are believed to contain a near-census of airbag-related fatalities in crashes of minor to moderate severity (delta-v < 25 mph) .

Air Bags Enter the Fleet



Number of dual air bag-equipped cars/light trucks in fleet grew from:

600,000 in 1992
to
40,000,000 in 1997

(Source: R.L. Polk registration data)

The air bags saved lives BUT in some cases caused fatal injuries, particularly to children:
70 air bag related child fatalities during the years 1993-1997

Responses to Air Bag Injuries



- Public education
 - 1996: Safety campaigns launched by NHTSA and its partners – manufacturers, insurance companies, and other organizations
 - Emphasized child and adult safety practices

Responses to Air Bag Injuries



■ Rulemaking

- March 1997: NHTSA rule allows manufacturers to reduce force at which air bags deploy

→ “Redesigned Air Bags”

More accurately called “Sled-Certified Air Bags”

Optional sled test vs. previously required barrier test

Vehicles certified to new standard enter fleet throughout 1998 model year

- May 2000: Final Rule, Advanced Air Bags

Responses to Air Bag Injuries



Were the measures effective?

To answer, compare counts across years:

- Align fatality counts into Sept-Aug production years
- Divide by “Million Registered Vehicle Years” (MRVY):

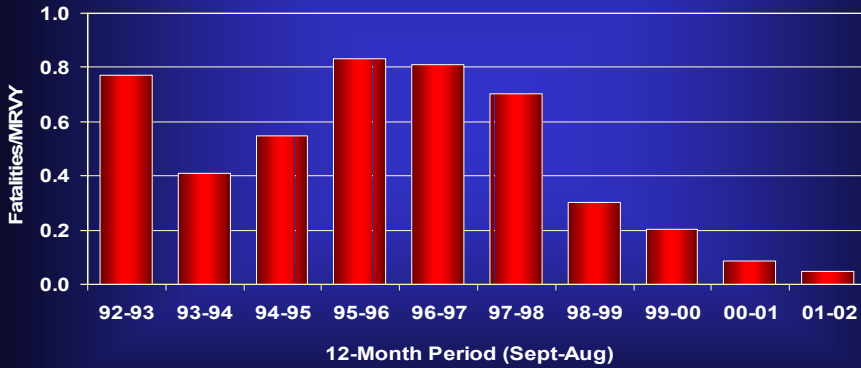
Estimated number of (driver/pass.) airbag-equipped vehicles on road during production year (in millions)

-adjusted for attrition and gradual release

Air Bag Fatalities Among Child Passengers



Children Fatally Injured by a Passenger Air Bag Normalized by Million Registered Vehicle Years

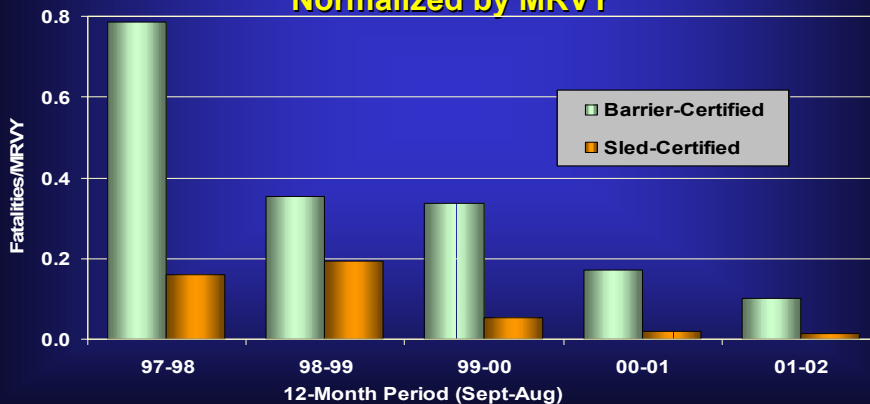


Source: NCSA, NHTSA

Air Bag Fatalities Among Child Passengers



Children Fatally Injured by a Passenger Air Bag Barrier-Certified Air Bags vs. Sled-Certified Air Bags Normalized by MRVY



Source: NCSA, NHTSA

Sled-Certified Air Bags



Fatal injuries confirmed to have been caused by a deploying sled-certified passenger air bag were sustained by:

8 children ages 2-8 – 4 head, 4 neck

- All unbelted
- 3 on lap of right front passenger
- Pre-impact braking in 7 of the 8

1 male age 85, hgt/wgt unk - head

Sled-Certified Air Bags



Fatal injuries confirmed to have been caused by a deploying sled-certified driver air bag were sustained by:

1 female age 48 5' 5" – belted - head

1 female age 80 5' 7" – not belted - chest

1 male age 70 hgt/wgt unk. – not belted- chest

1 infant on lap of driver – on-lap - head

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Sled-Certified Air Bags



- **In FY1999 (October 1998) NHTSA initiated a Redesigned Air Bag Special Study (RABSS)**
 - **Target: cases of high interest located by the SCI teams and the National Automotive Sampling System (NASS) teams.**
 - RABSS is NOT a random sample
 - **Emphasis on the protective benefit of sled-certified air bags**

RABSS Criteria



- **Minimum Criteria:**
 - **Vehicle with a sled-certified air bag in frontal impact, towed, with occupant in position where air bag deployed**
- **Cases of Highest Interest:**
 - **Children in front of deploying bag (injured or not)**
 - **Fatals (any age)**
 - **Injuries requiring transport to medical facility**
 - **Delta V > 25**

RABSS Special Evaluations



- **NHTSA contracted for an Air Bag Analysis**
 - **Two engineers independently reviewed over 400 cases from RABSS**
 - **447 drivers**
 - **143 adult front passengers**
 - **31 child right/other front passengers**

Total 621 assessments

RABSS Special Evaluations



The evaluators judged whether there was steering wheel or instrument panel deformation related to occupant loading subsequent to an air bag deployment.

- Their assessment was “yes” for 30 drivers
 - 9 fatalities among the 30
 - Other 21 had at least moderate (AIS at least 2) injuries
- Their assessment was “no” for 387 drivers
 - 5 fatalities among the 387
 - 85 moderate to severe injury
 - 297 none/minor

Right front passengers were also examined, but assessment was “no” for all right front occupants where assessment made.

RABSS Special Evaluations



Driver air bag deployment with steering wheel rim/column deformation related to occupant loading cases:

Selected variable means by injury severity

Injury Severity	Count	Delta V (mph)	Weight (lbs)	BMI	Belted
AIS 0/1	0	-	-	-	-
AIS 2	6	23.5	186.7	27.7	17 %
AIS 3	10	26.6	181.9	27.4	30 %
AIS 4/5	5	35.2	193.8	28.2	80 %
Fatal	9	34.5	262.1	39.0	0 %

- 8 of 9 fatalities were male
- all 9 were in smaller passenger cars
- 2 head, 7 chest

RABSS Special Evaluations



Driver air bag deployment with little or no steering wheel rim/column deformation related to occupant loading cases:

Selected variable means by injury severity

Injury Severity	Count	Delta V (mph)	Weight (lbs)	BMI	Belted
AIS 0/1	297	15.7	164.9	25.4	83.1 %
AIS 2	54	19.8	174.8	25.2	77.8 %
AIS 3	27	26.7	172.1	25.7	55.6 %
AIS 4/5	4	22.7	125.7	20.4	100 %
Fatal	5	34.4	178.2	28.2	80.0 %

Special Crash Investigations Advanced Air Bags



- Caveat - RABSS cases were purposely selected for their high interest value:
means and rates can not be generalized to the general population

Special Crash Investigations Advanced Air Bags



- The SCI teams have begun data collection on crashes with air bags certified to the new advanced standard
- SCI is not aware of any cases where an advanced certified air bag failed to protect an occupant from a fatal or life-threatening injury...

...nor any cases with a fatal or life-threatening injury related to a deploying advanced air bag.



Data Availability WWW Case Viewing



- Preliminary Case Viewer
 - In 2002, NCSA began making clinical observations of the NASS CDS cases available via the WWW
 - <http://www-nass.nhtsa.dot.gov/nass/prapproved/disclaimer.html>
- NASS CDS Cases
 - 1997 on
 - <http://www-nass.nhtsa.dot.gov/BIN/NASSCASELIST.EXE/SETFILTER>
- SCI Cases
 - All confirmed cases
 - All RABSS cases
 - <http://www-nass.nhtsa.dot.gov/BIN/logon.exe/airmislogon>

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Air Bag Inflator and Location



	Time gap between Inflator Stages (msec)					Passenger Bag Location
	Seat	Driver		Passenger		
	Inflator Mode	Low	High	Low	High	
2001 Honda Accord		20	0	30	0	Top
2001 Chevy Impala		Primary Stage Only	4	Primary Only	4	Mid
2001 Dodge Caravan		Primary Stage Only	0	Primary Only	0	Mid
2001 Toyota Echo		N/A	N/A	N/A	N/A	Top
2001 Ford Escape		N/A	N/A	N/A	N/A	Front
2001 Ford F150		N/A	N/A	N/A	N/A	Mid

Hybrid III 6yo - Position 1



Chest on Instrument Panel

Hybrid III 6YO Position 1 Normalized Injury Criteria						
Vehicle	HEAD	CHEST		NECK		
	15ms HIC	3ms Clip Accel.	Deflection	NIJ	Neck Tension	Neck Comp.
2001 Toyota Echo	0.001	0.548	0.72	0.998	0.783	0.078
2001 Ford Escape	0.42	0.477	0.788	0.659	0.895	0.3
2001 Ford F150	0.097	0.625	1.303	1.415	1.714	0.004
2001 Honda Accord (low)	0.054	0.238	0.461	1.378	1.061	0.01
2001 Dodge Caravan (low)	0.243	0.506	0.623	1.996	2.264	0.005
2001 Dodge Caravan (high)	0.217	0.571	0.713	1.979	1.865	0.004
2001 Chevrolet Impala (low)	0.043	0.371	0.718	1.095	1.094	0.004

Hybrid III 6yo - Position 2



Head on Instrument Panel

Hybrid III 6YO Position 2 Normalized Injury Criteria						
Vehicle	HEAD	CHEST		NECK		
	15ms HIC	3ms Clip Accel.	Deflection	NIJ	Neck Tension	Neck Comp.
2001 Toyota Echo	0.059	0.221	0.06	1.128	0.383	0.783
2001 Ford Escape	0.506	0.595	0.63	2.494	2.745	0.519
2001 Ford F150	0.329	0.577	1.105	1.681	2.019	0.015
2001 Honda Accord (low)	0.273	0.247	0.028	0.695	0.557	0.724
2001 Dodge Caravan (low)	1.62	0.768	0.209	1.593	1.993	0.179
2001 Dodge Caravan (high)	1.93	0.872	0.892	2.224	2.267	0.016
2001 Chevrolet Impala (low)	0.586	0.266	0.028	1.016	1.004	0.004

Hybrid III 5th Female - Position 1



Chin on Air Bag Module

Hybrid III 5th Female Position 1 Normalized Injury Criteria						
Vehicle	HEAD	CHEST		NECK		
	15ms HIC	3ms Clip Accel.	Deflection	NIJ	Neck Tension	Neck Comp.
2001 Toyota Echo	0.071	0.247	0.247	0.728	0.678	0.004
2001 Ford Escape	0.039	0.281	0.451	1.493	0.6	0.009
2001 Ford F150	0.03	0.26	0.428	1.386	0.841	0.157
2001 Honda Accord (low)	0.039	0.243	0.203	0.31	0.455	0.044
2001 Dodge Caravan (low)	0.023	0.418	0.718	0.736	0.905	0.092
2001 Dodge Caravan (high)	0.061	0.483	0.815	1.87	1.113	0.041
2001 Chevrolet Impala (low)	0.007	0.314	0.483	0.229	0.322	0.048
2001 Chevrolet Impala (high)	0.044	0.263	0.258	0.411	0.32	0.04

Hybrid III 5th Female - Position 2



Chin on Steering Wheel Rim

Hybrid III 5th Female Position 2 Normalized Injury Criteria						
Vehicle	HEAD	CHEST		NECK		
	15ms HIC	3ms Clip Accel.	Deflection	NIJ	Neck Tension	Neck Comp.
2001 Toyota Echo	0.023	0.48	0.553	0.67	0.394	0.01
2001 Ford Escape	0.036	0.664	1.003	0.59	0.384	0.018
2001 Ford F150	0.027	0.621	0.931	0.582	0.479	0.02
2001 Honda Accord (low)	0.061	0.422	0.607	1.015	0.52	0.065
2001 Dodge Caravan (low)	0.04	0.586	1.217	0.67	0.828	0.129
2001 Dodge Caravan (high)	0.06	0.667	1.241	0.845	0.741	0.027
2001 Chevrolet Impala (low)	0.01	0.264	0.54	0.273	0.181	0.054
2001 Chevrolet Impala (high)	0.027	0.278	0.756	0.493	0.285	0.041

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Test Program



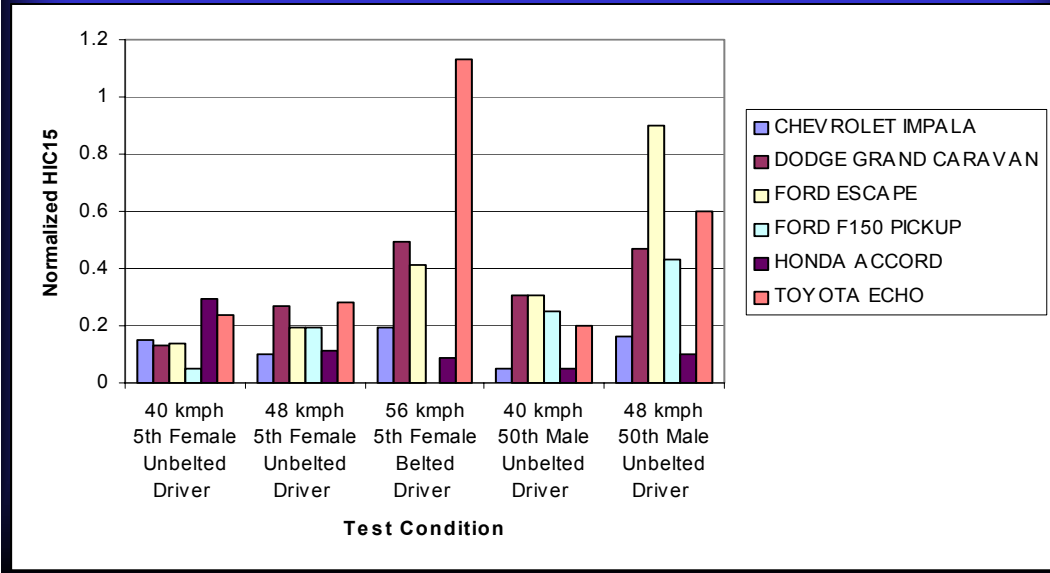
- **40 and 48 Km/H Rigid Barrier Tests**
 - **Unbelted 50th percentile dummy**
 - **Unbelted 5th percentile dummy**
- **56 Km/H Rigid Barrier Tests**
 - **Belted 5th percentile dummy**

Test Matrix – MY2001 Rigid Barrier Frontal Crash Tests



		Occupant => Restraint => Speed (kmph) =>	5th Female		50th Male	
			Unbelted	Belted	Unbelted	
		Mass (kg)	40	48	56	40
Vehicle	Class	Mass (kg)				
Chevy Impala	Medium Pass. Car	1566	x	x	x	x
Dodge Caravan	Minivan	1761	x	x	x	x
Ford Escape	SUV	1391	x	x	x	x
Ford F-150 Pickup	Pickup Truck	2122	x	x		x
Honda Accord	Medium Pass. Car	1399	x	x	x	x
Toyota Echo	Light Pass. Car	982	x	x	x	x
Nissan Maxima	Medium Pass. Car	1470			x	
Dodge Durango	SUV	2140			x	
Nissan Sentra	Compact Pass. Car	1255			x	
Ford Windstar	Minivan	1875			x	
Honda Civic	Compact Pass. Car	1146			x	

Driver's Side: 15ms HIC



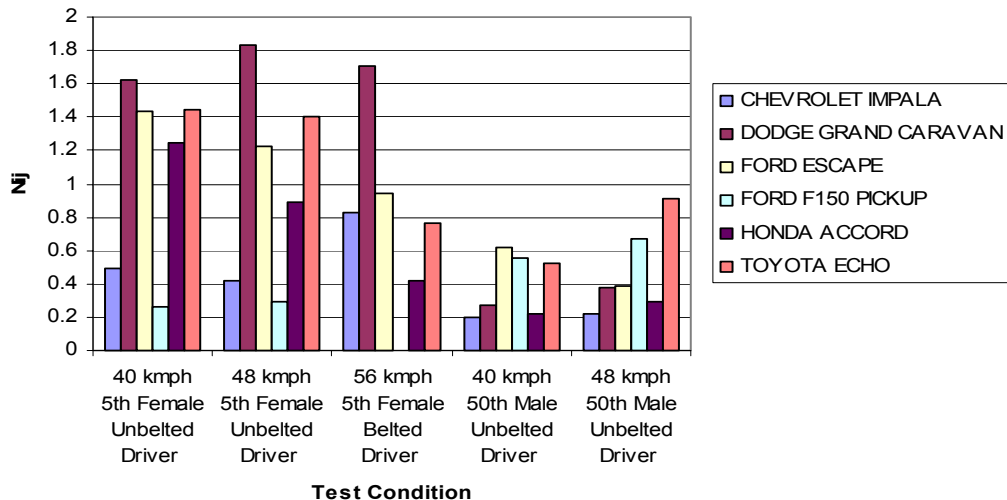
Head Contact

- Head contact with windshield, steering wheel, and other hard interior points occurred in
 - the unbelted 50th male tests at 40 and 48 kmph, and
 - the unbelted 5th female at 40 kmph, to a lesser extent.

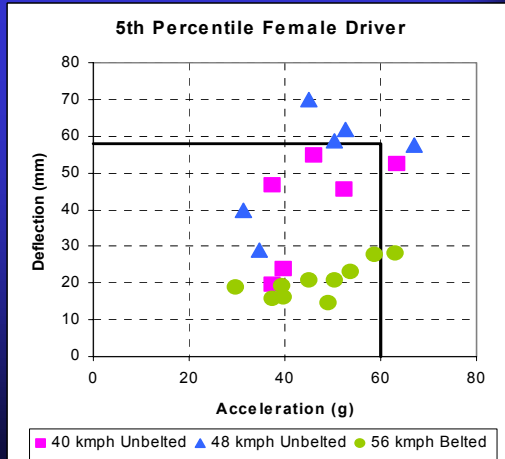
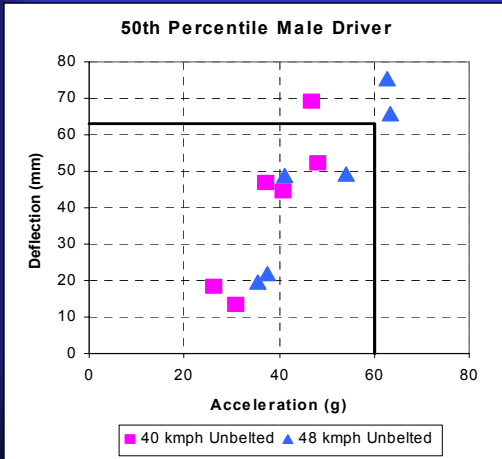


Test 3902 50th Male driver occupant showing windshield glass-to-head contact.

Driver's Side: Nij



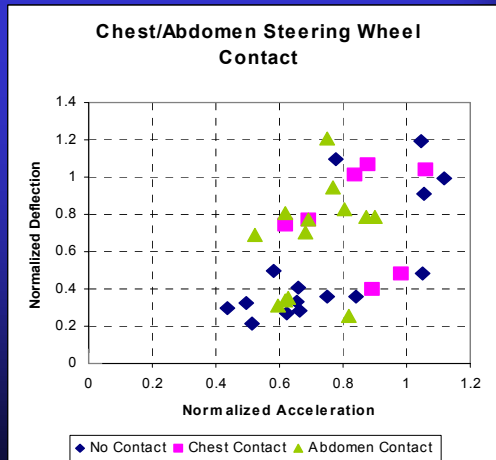
Chest Injury



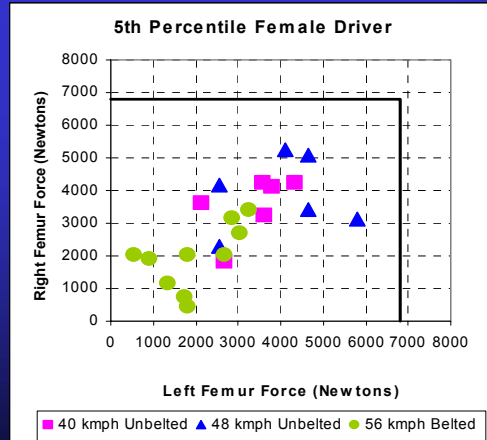
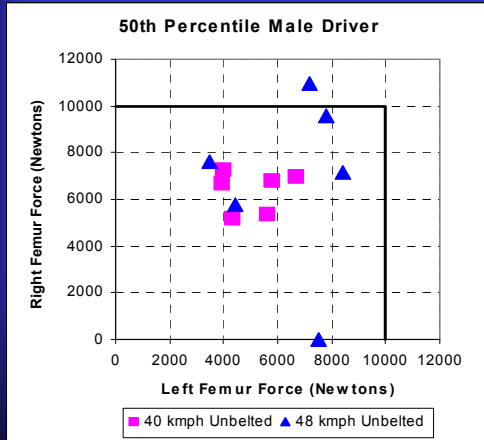
Abdomen-to-Steering Wheel Contact



Test 3805 50th Male driver occupant showing transfer paint witness marks indicating steering wheel-to-occupant contact.



Femur Injury



Summary

Real World:

- Air bag fatalities down after advent of public safety campaigns and sled-certified air bags, but some unbelted children have still sustained fatal injuries.
- Some unbelted heavier drivers in smaller car severe crashes may have loaded steering wheel or rim subsequent to a sled-certified air bag deployment in extreme cases.

Crash Testing:

- Head contact with the windshield and header was observed in the unbelted 50th percentile male tests, indicating that the air bag alone was not sufficient to restrain the mid-sized male occupant.
- Abdomen-to-steering wheel contact was observed in this test series.

Summary



Low Risk (OOP) Deployment:

- The first stages of the dual stage inflator air bags were powerful enough to prevent the 6YO from meeting the Low-Risk Deployment (OOP) Air Bag Testing requirements of the FMVSS 208 Advanced Air Bag Rule.
- Neck Injury Criteria failures were dominant in the 6yo tests.
- Neck Injury (Nij) and Chest Deflection failures were dominant in the 5th percentile female tests.
- There are vehicles whose air bags are not certified to, but can meet the requirements of, the FMVSS 208 Advanced Air Bag Rule for the 5th percentile female OOP testing.
- None of the vehicles chosen could pass both the 5th female and the 6YO OOP performance requirements.

2003 ESV Publications



- Kindelberger et al. *Air Bag Crash Investigations Paper No.299-W*
- Prasad et al. *Injury Risks from Advanced Air Bags in Frontal Static Out-of-Position Tests Paper No.427-O*
- Maltese et al. *Vehicle Performance In Full-Frontal Crash Tests With Small Female And Mid-Sized Male Occupants Paper No.414-O*

Questions ?

Restraint Systems Details

Vehicle	Dual Stage Air Bags	Force Limited Seatbelts	Pre-tensioners in Seatbelts	Integrated Seatbelts
2001 Ford Escape		•	•	
2001 Toyota Echo		•	•	
2001 Ford F150		•	•	•
2001 Honda Accord	•	•	•	
2001 Dodge Caravan	•	•	•	
2001 Chevrolet Impala	•	•		