THE UNIVERSITY OF
ALABAMA AT BIRMINGHAM
Crash Injury Research & Engineering Network

Side Airbag Effectiveness: A Matched Cohort Study Using CIREN and NASS/CDS

University of Alabama at Birmingham
CIREN Center

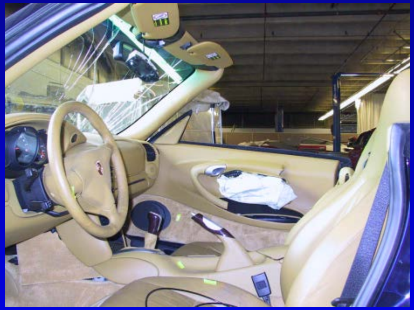
Background

- Side-impact airbags (SABs) were first introduced in 1995
  - According to the Insurance Institute for Highway Safety (IIHS), SABs were standard in:
    - Volvo 850, S90, V90 models
    - Mercedes Benz E Class and SL Class models

Background

- SAB types
  - Head-protecting
    - Deploy from roof-side rail

  - Torso-protecting
    - Deploy from door panel or seat back
    - Early SABs only torso-protecting



Background

Percent side airbag availability by protection area

		2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995
Head/torso	Standard	83.1	77.0	64.5	58.9	47.6	38.3	31.9	27.0	22.1	20.3	18.6	10.1	5.4	1.3			
	Optional	2.6	0.8	5.3	6.8	11.5	15.3	15.6	12.3	10.3	8.8	9.4	6.9	2.2				
Head only	Standard	7.9	10.4	11.9	9.8	3.7	1.9	1.8	1.7	1.5	0.4							
	Optional	1.7	2.2	6.9	9.7	15.1	14.8	13.6	8.4	6.2	3.7	1.4						
Torso only	Standard	1.0	1.1	1.0	2.0	2.3	5.6	5.6	5.4	8.0	13.4	9.6	12.8	12.5	13.7	3.6		0.4
	Optional				0.1	0.1	3.3	5.7	10.8	10.9	4.6	4.3	2.4	2.6	1.9	0.4	1.3	
Not available		3.7	8.4	10.3	12.6	19.7	20.8	25.8	34.4	41.0	48.9	56.8	67.7	77.3	83.1	96.0	98.7	99.6

Source: Insurance Institute for Highway Safety

Background

	No SAB	Optional	Standard
Overall	67.8	20.7	11.5

Source: NHTSA General Estimates System

Background

	No SAB	Optional	Standard
Age			
16-29	72.3	19.4	8.3
30-39	66.2	21.7	12.1
40-49	66.2	21.0	12.8
50-59	64.3	21.4	14.3
60+	63.3	22.0	14.8

Source: NHTSA General Estimates System

Background

- SABs have been reported to be effective in reducing side-impact MVC mortality
  - McCartt et al. (2007)
    - 37% reduction for head-protecting SABs
    - 26% reduction for torso-only SABs
  - Braver et al. (2004)
    - 45% reduction for head/torso SABs
    - 11% reduction for torso-only SABs

Background

- Results for non-fatal injuries have been less consistent, varying by injury type
  - McGwin et al. (2003)
    - No difference in overall injury risk during near-side impacts between occupants with and without SAB availability
  - McGwin et al. (2004)
    - 25% reduction in risk for head, 32% reduction in risk of thoracic injury related to SAB availability in near-side impacts
  - McGwin et al. (2008)
    - 2.75-fold increase for AIS 2+ upper extremity injuries
    - 2.45-fold increase for upper extremity dislocation

Background

- Yoganandan et al. (2007)
  - NASS data for 1997-2004
  - Near-side impact collisions included
  - SABs reduce AIS 2+ head, chest and extremity injuries
  - Thorax injuries increased
  - Low sample size prohibited conclusive evidence
  - Suggested future studies combine NASS/CDS data with CIREN data

Background

- Limitations of prior research
  - Relied on SAB availability rather than deployment
  - Focused on near-side impacts, which represent a portion of all SAB deployments in MVCs
  - Limited sample size due to SABs being a newer technology
  - Residual confounding

Objective

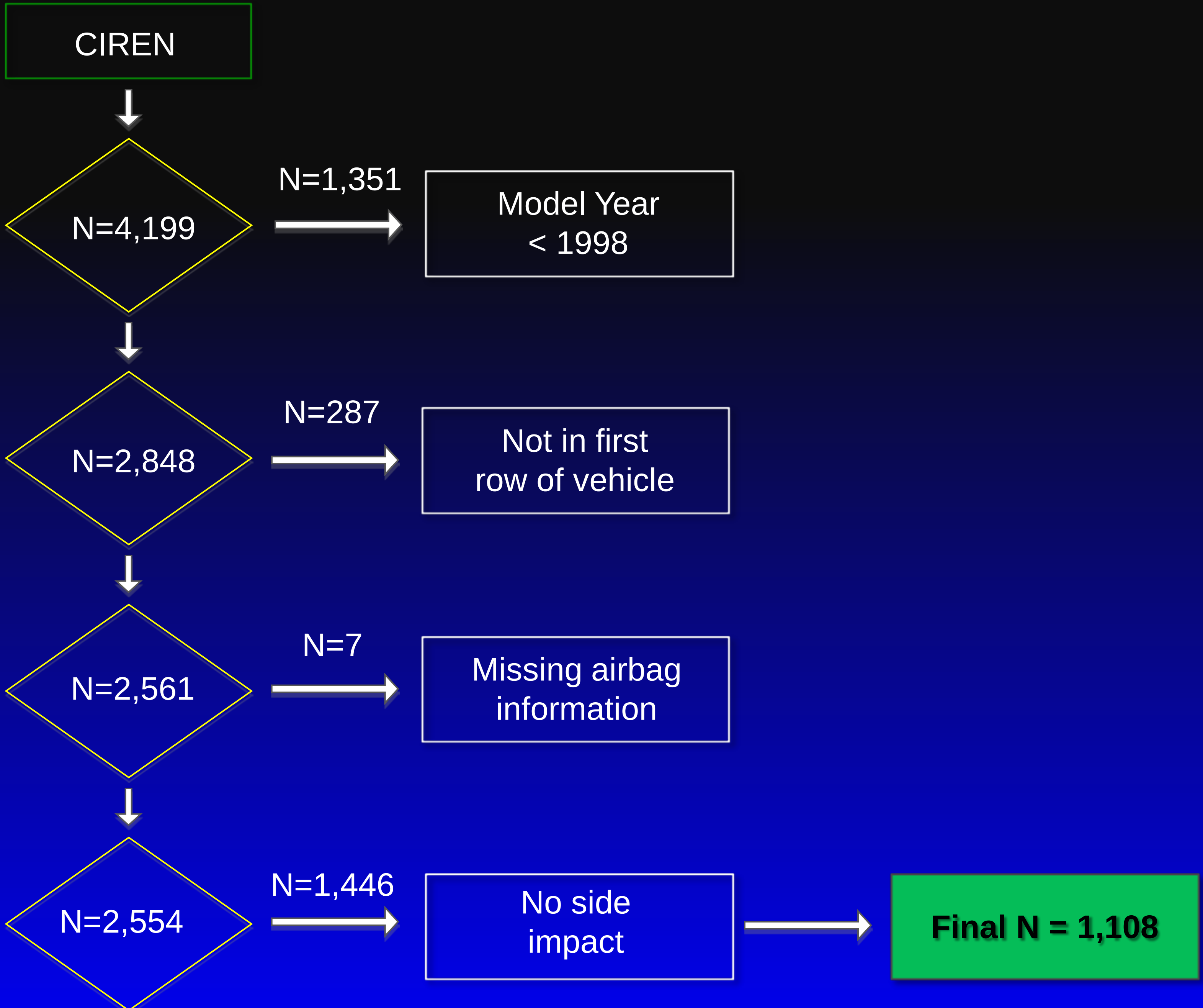
- Assess effectiveness of SABs in reducing head and thoracic injury to front-seated occupants of MVCs
    - Prior biomechanical research has reported on the efficacy of SABs in reducing injury (i.e., ability to protect occupants from injury in a controlled environment)
    - Prior epidemiological research regarding SAB effectiveness limited due to reliance of SAB availability and small sample size

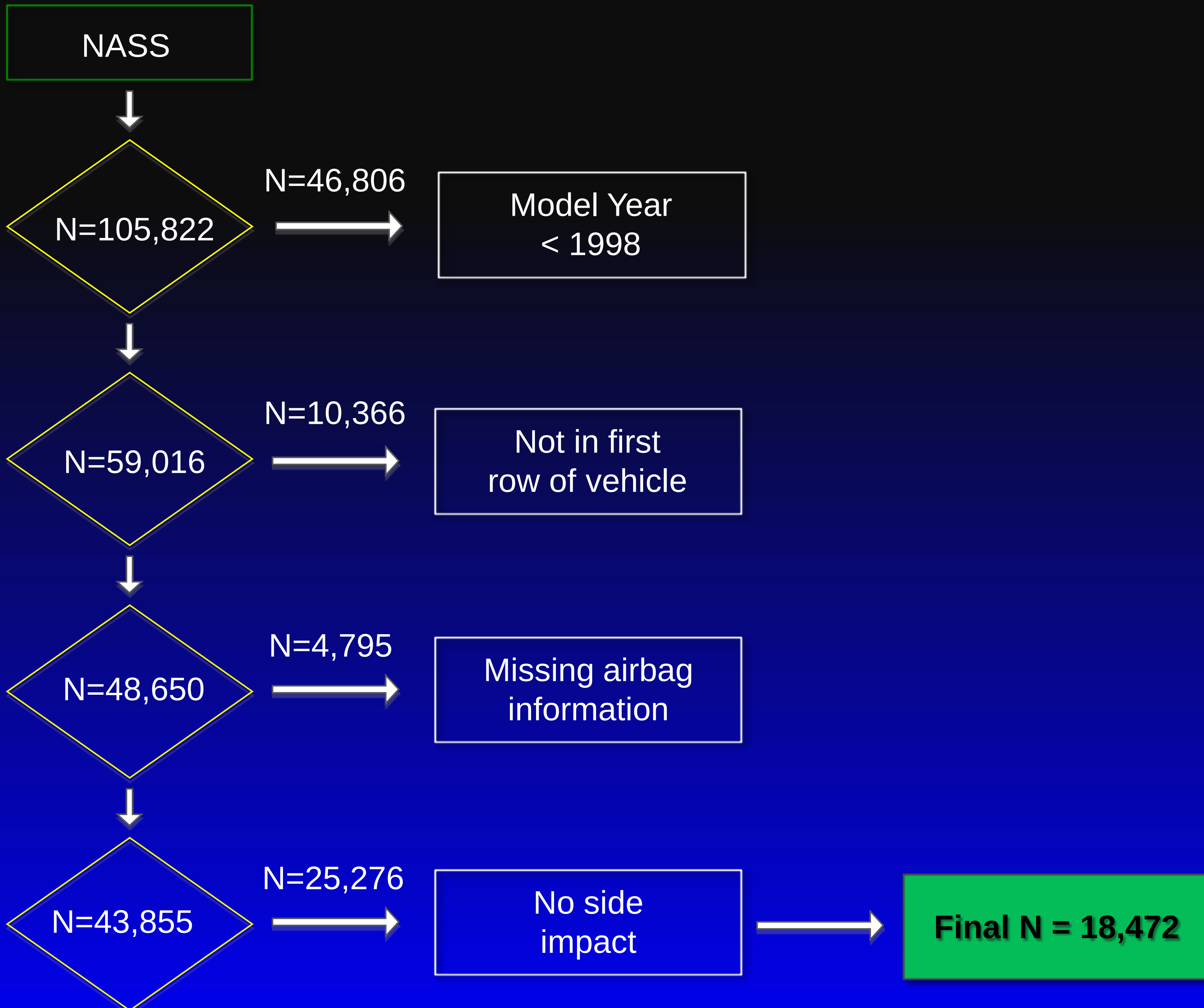
Methods

- Study Design – Retrospective, matched cohort study

- Data Sources – CIREN and NASS/CDS data 2000-2009

    - Pseudo-weights were used to combine data sources according to the technique described by Elliott et al.

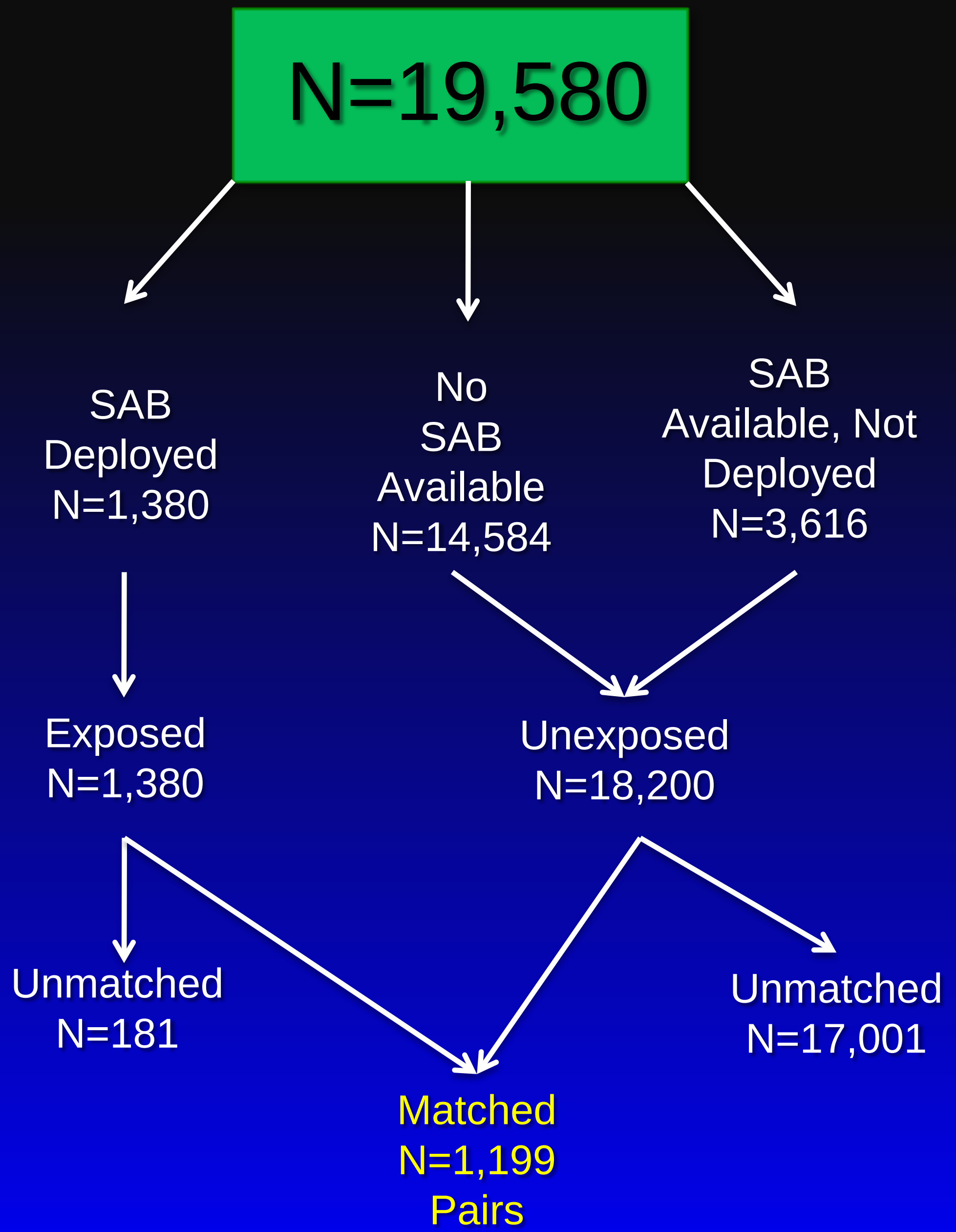

CIREN
N=4,199
N=1,351
Model Year
< 1998
N=2,848
N=287
Not in first
row of vehicle
N=2,561
N=7
Missing airbag
information
N=2,554
N=1,446
No side
impact
Final N = 1,108


NASS
N=105,822
N=46,806
Model Year
< 1998
N=59,016
N=10,366
Not in first
row of vehicle
N=48,650
N=4,795
Missing airbag
information
N=43,855
N=25,276
No side
impact
Final N = 18,472

N=19,580

Methods

- Front-seated occupants whose SAB deployed were matched to front-seated occupants who had no SAB deployment based on:
  - Gender
  - Age ± 5 years
  - Initial object the vehicle hit (i.e., vehicle, fixed object)
  - Direction of force (±10^{o}) of collision impact
  - Occupant seating position (driver/front passenger)
  - General area of damage (L or R) to vehicle side
  - Vehicle body type (passenger car, SUV/van, truck)
  - Pseudo-sampling weight ± 1500


N=19,580
SAB Deployed N=1,380
No SAB Available N=14,584
SAB Available, Not Deployed N=3,616
Exposed N=1,380
Unexposed N=18,200
Unmatched N=181
Unmatched N=17,001
Matched N=1,199 Pairs

Example Matched Pair

Exposed

PSU: 13

Case Number: 105

Stratum: E

Weight: 85.306

Crash Date: 05/2009

Vehicle:

Year/Make/Model: 2009 Subaru Impreza

Example Matched Pair

Unexposed

PSU: 13

Case Number: 012

Stratum: E

Weight: 97.601

Crash Date: 01/2006

Vehicle:

- Year/Make/Model: 2005 Pontiac Grand Prix

Example Matched Pair

Exposed Summary

Crash Type: Vehicle to vehicle

Configuration: Angle/sideswipe

PDOF: 300

Delta-V: 18 km/h

Summary: Vehicle 1, traveling south when it was struck in the LF by westbound vehicle 2. The vehicles then side-slapped and vehicle 2 struck a sign before coming to rest.

Example Matched Pair

Unexposed Summary

Crash Type: Vehicle to vehicle

Configuration: Angle/sideswipe

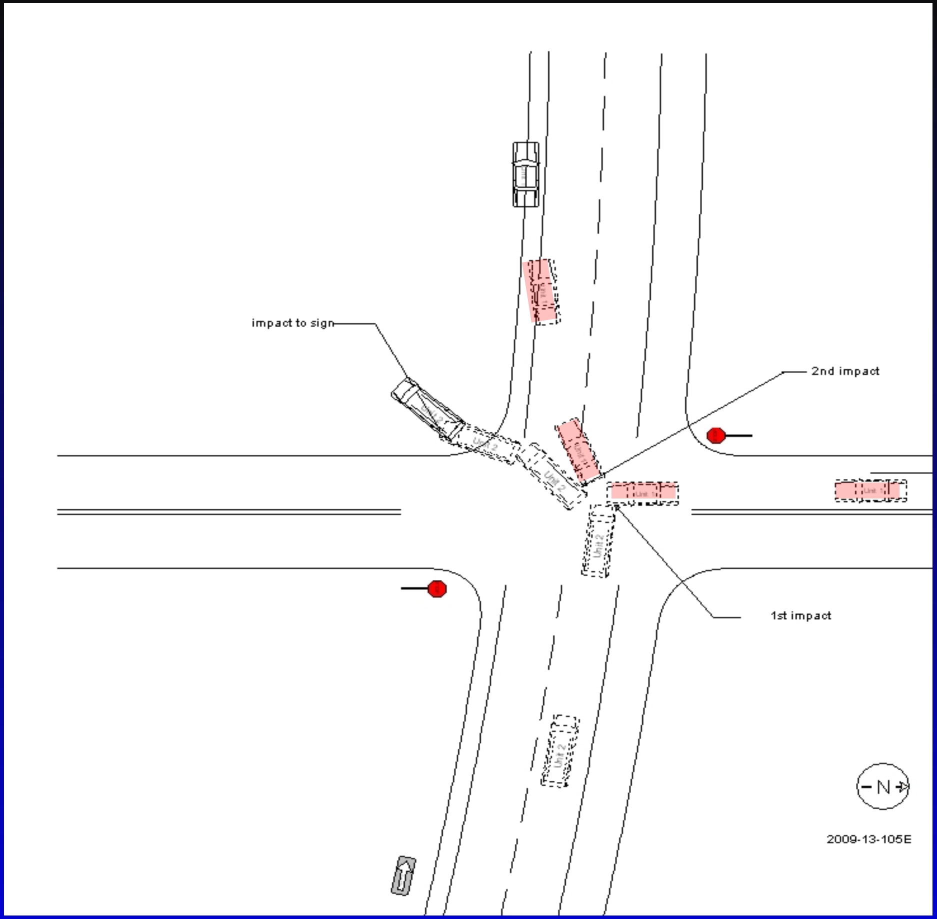
PDOF: 300

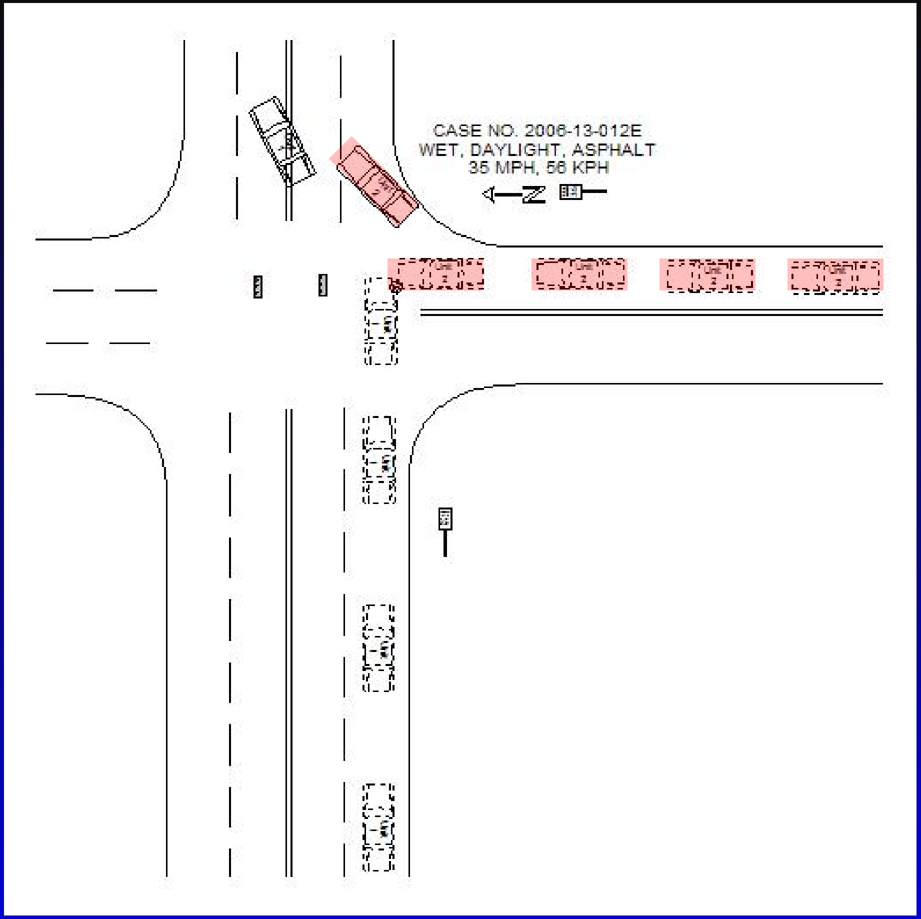
Delta-V: 12 km/h

Summary: Vehicle 1, was eastbound in lane 1 of a four lane city street. Vehicle 2 was northbound on a two lane intersecting street. Both streets had a 35 mph speed limit and the intersection is controlled by traffic signals. As Vehicle 1 entered the intersection it was contacted in the right front by the left front of vehicle 2.

Exposed

Unexposed





Exposed Vehicle

Unexposed Vehicle

Methods

- Statistical Analysis
  - Demographic, vehicle, and collision characteristics compared between SAB deployment groups using McNemar's and paired t-test for categorical and continuous variables, respectively

Methods

- Conditional logistic regression (adjusted for ΔV) used to estimate the association between SAB deployment and AIS 2+ injury to head or thorax
  - Stratified by object hit in primary impact (i.e., vehicle or fixed object)
  - Further stratified by direction of initial impact (i.e., frontal, near-side, or far-side)
  - Stratified by age

Table 1. Comparison of demographic, vehicle/occupant, and collision characteristics by side airbag deployment

	SAB Deployment (n=1,199)	No SAB Deployment (n=1,199)	p-value
Demographics			
Male, %	52.5	52.5	-
Age (years), mean	37.3	37.2	-
Height (cm.), mean	171.0	171.2	0.7121
Weight (kg), mean	76.3	77.7	0.1060

Table 1 (cont.). Comparison of demographic, vehicle/occupant, and collision characteristics by side airbag deployment

	SAB Deployment (n=1,199)	No SAB Deployment (n=1,199)	p-value
Vehicle/Occupant	%	%	
Seat Position			-
Driver	78.6	78.6	
Front passenger	21.4	21.4	
Seatbelt Use, yes	83.2	80.1	0.0509
Vehicle Body Type			-
Passenger car	75.2	75.2	
SUV/Van	24.3	24.3	
Truck	0.5	0.5	
Vehicle Model Year			<0.0001
1998-2000	14.8	42.0	
2001-2003	31.9	32.5	
2004-2006	31.8	21.4	
2007-2010	21.6	4.1	

Table 1 (cont.). Comparison of demographic, vehicle/occupant, and collision characteristics by side airbag deployment

	SAB Deployment (n=1,199)	No SAB Deployment (n=1,199)	p-value
Collision	%	%	
Impact			
Frontal	62.3	62.3	0.9653
Near-side	30.3	30.9	
Far-side	3.8	3.8	
Rear	3.5	3.1	
Rollover	17.1	15.1	0.1872
Ejection	6.8	7.4	0.5392
Total ΔV (km/h)			
0-24	38.3	40.3	0.0779
25-49	57.9	54.2	
50+	3.8	5.5	
Vehicle crush (cm.)			
0-39	66.5	62.1	0.0435
40-59	19.5	24.3	
60-79	8.9	7.5	
80+	5.1	6.1	

NASS CDS Example

PSU: 6

Case Number: 004

Stratum: C

Weight: 18.258

Crash Date: 01/2009

Day Of Week: Thursday

Crash Time: 15:15

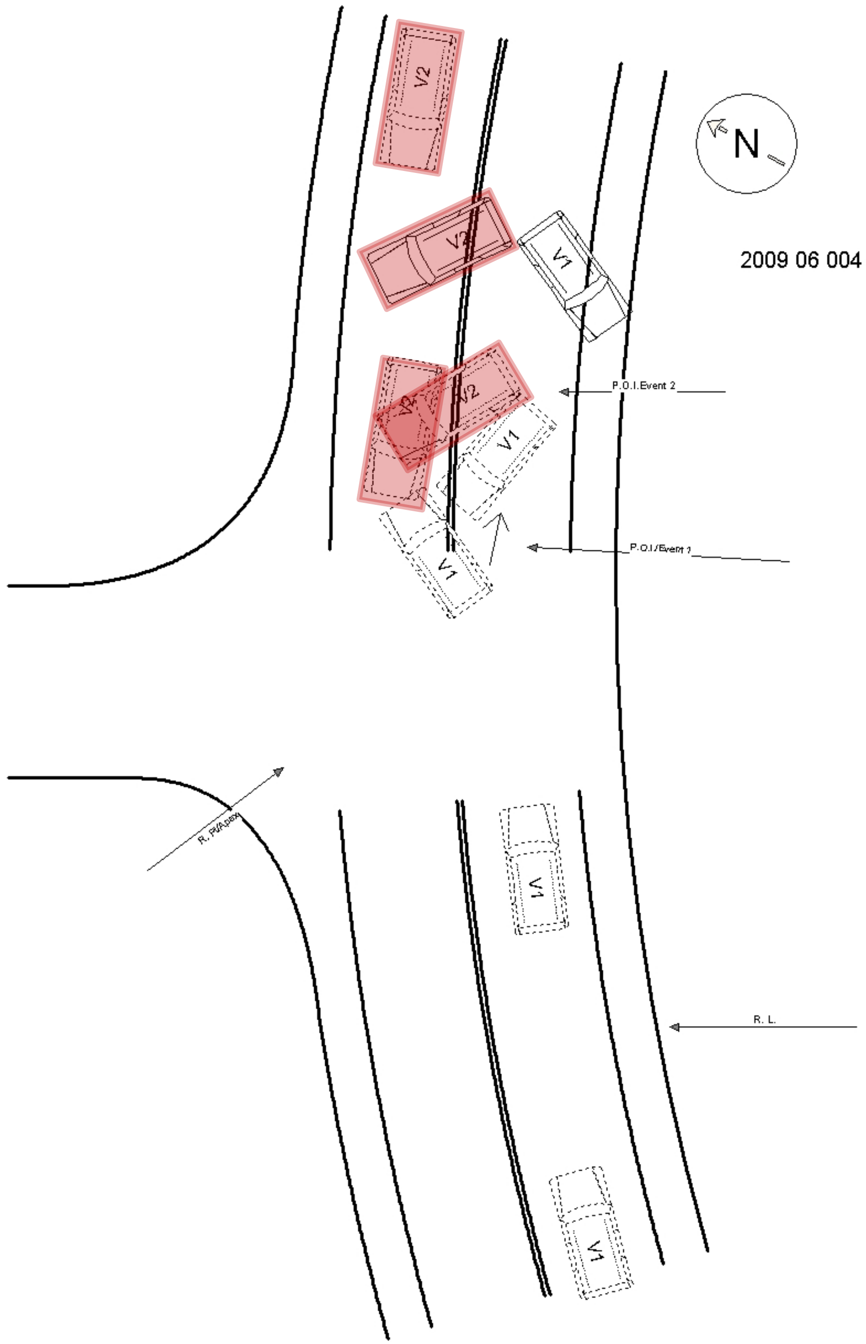
NASS CDS Example

- **Case Summary:**

  Crash Type: Vehicle to vehicle

  Configuration: Head-on

  Summary: V1 was traveling northeast when the front came in contact with the front of V2. V2 had been traveling southwest on the same roadway. After the initial impact, V1 then spun counterclockwise and the right rear side came into contact with the left rear side of V2. V2 had spun in a clockwise direction. The driver of V1 was ejected from his vehicle.


N
2009 06 004
V2
V1
P.O.I.Event 2
P.O.I./Event 1
R. Pt/Apex
R. L.

Vehicle 2

Table 2. Risk ratios (RR) and 95% confidence intervals (95% CI) for the association between side airbag (SAB) deployment and AIS 2+ injury

	Risk (per 100)		
	SAB deployed (n=1,199)	**No SAB deployed (n=1,199)**	**RR (95% CI)†**
Head Injury			
All collisions	19.8	21.3	0.86 (0.70-1.07)
Vehicle vs. vehicle	14.9	15.6	0.81 (0.60-1.09)
Vehicle vs. fixed object	31.7	35.6	0.87 (0.62-1.22)
Thorax Injury			
All collisions	23.2	21.6	1.02 (0.83-1.27)
Vehicle vs. vehicle	18.3	17.5	0.92 (0.69-1.23)
Vehicle vs. fixed object	35.3	31.1	1.11 (0.79-1.57)

† Adjusted for ΔV

Table 3. Risk ratios (RR) and 95% confidence intervals (95% CI) for the association between head side airbag (hSAB) deployment and AIS 2+ injury

	Risk (per 100)		
	hSAB deployed (n=681)	**No hSAB deployed (n=681)**	**RR (95% CI)†**
Head Injury			
All collisions	14.2	19.5	0.70 (0.51-0.97)
Vehicle vs. vehicle	10.6	14.3	0.66 (0.42-1.03)
Vehicle vs. fixed object	25.3	35.8	0.70 (0.43-1.14)

† Adjusted for ΔV

Table 4. Risk ratios (RR) and 95% confidence intervals (95% CI) for the association between torso side airbag (tSBA) deployment and AIS2+ injury

	Risk (per 100)		
	tSAB deployed (n=1,000)	**No tSAB deployed (n=1,000)**	**RR (95% CI)†**
Thorax Injury			
All collisions	24.6	23.0	0.99 (0.79-1.24)
Vehicle vs. vehicle	20.7	18.5	0.93 (0.69-1.26)
Vehicle vs. fixed object	33.4	32.4	0.96 (0.66-1.38)

† Adjusted for ΔV

Table 5a. Risk ratios and 95% confidence intervals for the association between **head side airbag** deployment and AIS 2+ head injury by direction of initial impact

	Frontal (n=412 pairs)	Near-Side (n=163 pairs)	Far-Side (n=29 pairs)
Head Injury	RR (95% CI)†	RR (95% CI)†	RR (95% CI)†
All collisions	0.67 (0.43-1.04)	0.65 (0.33-1.29)	0.61 (0.11-3.53)
Vehicle vs. vehicle	0.66 (0.36-1.22)	0.68 (0.29-1.58)	0.87 (0.10-7.33)
Vehicle vs. fixed object	0.57 (0.28-1.17)	0.57 (0.17-1.96)	0.31 (0.01-8.31)

† Adjusted for ΔV

Table 5b. Risk ratios and 95% confidence intervals for the association between **torso side airbag** deployment and AIS 2+ thorax injury by direction of initial impact

	Frontal (n=569 pairs)	Near-Side (n=293 pairs)	Far-Side (n=25 pairs)
Thorax Injury	**RR (95% CI)†**	**RR (95% CI)†**	**RR (95% CI)†**
All collisions	1.00 (0.72-1.41)	1.00 (0.66-1.51)	0.36 (0.03-4.67)
Vehicle vs. vehicle	0.91 (0.58-1.41)	0.99 (0.61-1.61)	Undefined
Vehicle vs. fixed object	0.96 (0.52-1.75)	1.09 (0.49-2.43)	Undefined

† Adjusted for ΔV

Table 6. Risk ratios (RR) and 95% confidence intervals (95% CI) for the association between side airbag (SAB) deployment and AIS 2+ injury according to age

	Thorax Injury RR (95% CI)†	Head Injury RR (95% CI)†
Age		
<25	0.98 (0.62-1.54)	0.72 (0.43-1.22)
25-49	0.78 (0.53-1.13)	0.68 (0.37-1.23)
50+	1.27 (0.84-1.93)	0.91 (0.44-1.90)

† Adjusted for ΔV

Table 7. Involved physical component (IPC) – AIS 2+ head injury

	SAB deployed (%) N=949	**No SAB deployed (%) N=936**
Front (e.g., steering wheel)	1.5	3.8
Side (e.g., A/B pillar)	17.7	18.3
Door panel (e.g., armrest)	0.5	0.9
Roof (e.g., header)	8.9	9.2
Interior (e.g., seat, console)	1.6	1.8
Other vehicle or object	17.1	22.3
Noncontact (e.g., flying glass)	3.7	3.7
Airbag	0.4	-
Missing	48.7	40.0

Table 8. Involved physical component (IPC) – AIS 2+ thoracic injury

	SAB deployed (%) N=943	**No SAB deployed (%) N=850**
Front (e.g., steering wheel)	2.2	5.8
Side (e.g., A/B pillar)	25.7	32.5
Door panel (e.g., armrest)	8.9	3.8
Floor (e.g., toe pan)	0.5	0.9
Roof (e.g., header)	0.5	0.4
Interior (e.g., seat, console)	4.5	3.6
Other vehicle or object	4.1	3.1
Noncontact (e.g., flying glass)	2.5	1.3
Airbag	0.5	-
Missing	50.5	48.2

Discussion

- SABs are associated with lower risk of AIS2+ head injuries
  - Effect sizes consistent with prior research
  - Head protection appears similar across collision types
  - Older occupants do not appear to benefit (as much)

- No associations for AIS2+ thorax injuries
  - Smaller (compared to thorax injuries) but meaningful associations observed in prior research
  - Consistent across collision types and age groups

Strengths

- Ability to determine SAB deployment rather than availability
- Combined CIREN and NASS/CDS data = larger sample size
- Inclusion of all impact types (rather than just near-side collisions) provides a more comprehensive assessment of SAB effectiveness on injury risk

Limitations

- Lack of detailed information available in controlled studies
  - Occupant position at time of SAB deployment
  - Knowledge of when, during the impact, the SAB deployed
- Previous research has suggested occupant position in relation to SAB is an important mechanism of injury protection
  - Hallman 2010, Hallman 2009, Yoganandan 2007

Next Steps

- Expand study base to capture all currently available data
  - Recalculate pseudo-weights
- Expand study population to include rear-seated occupants
- Calculate risk estimates according to specific SAB types
- Estimate associations for organ-specific injuries (e.g., splenic injury)
- Others…

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