Evaluation of Safety Systems Through Matched Comparison for Frontal, Side, and Knee Bolster Safety Systems

Joel D. Stitzel, Kathryn L. Loftis, Ashley R. Weaver,
Mao M. Yu, J. Wayne Meredith, R. Shayn Martin,
Christina P. Mullen, Dan Robertson, Masakasu Chiba

CIREN Public Meeting

October 2009

Dr. Joel D. Stitzel (jstitzel@wfubmc.edu)

TOYOTA

Toyota – Wake Forest University
School of Medicine
CIREN Center

WAKE FOREST UNIVERSITY
SCHOOL of MEDICINE

Purpose

- Find a way to utilize CIREN information to investigate vehicle safety advancements
- Develop methods for comparing regulatory crash test to real-world crashes
  - Dummy/occupant kinematics
  - Vehicle dynamics
  - Vehicle crashworthiness comparison
- Develop scoring system to identify cases that closely compare

Objectives

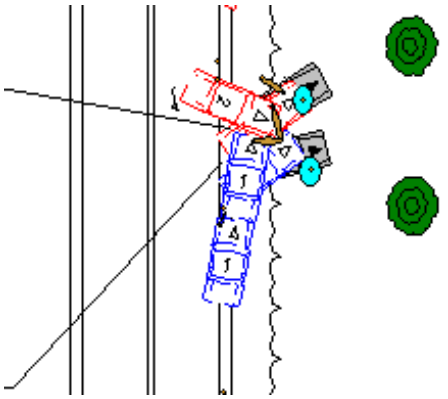
- Demonstrate a simple similarity scoring system for comparison to regulatory cases and between CIREN cases.
- Demonstrate CIREN as a tool for detailed comparison of cases with key dissimilar characteristics.
  - Primarily, with and without safety system usage (SB, SAB, KBAB).

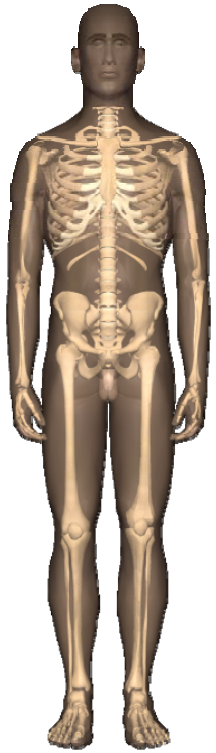
Presentation

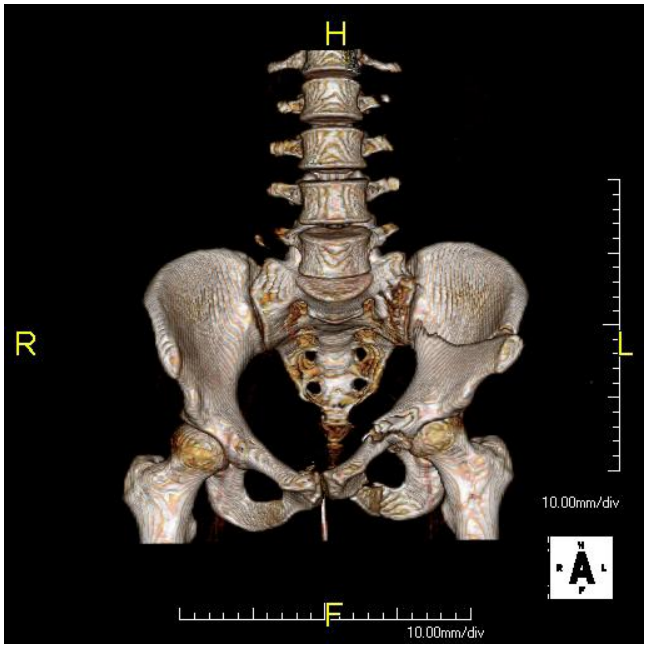
- Overview
- CIREN case comparisons to NHTSA crash tests
- Case Selection
  - Regulatory Matching
  - Similarity Comparison
- CIREN Case Comparisons
  - Frontal Impact
  - Side Impact
  - Knee Bolster Airbag
- Conclusions/Recommendations

Main characteristics

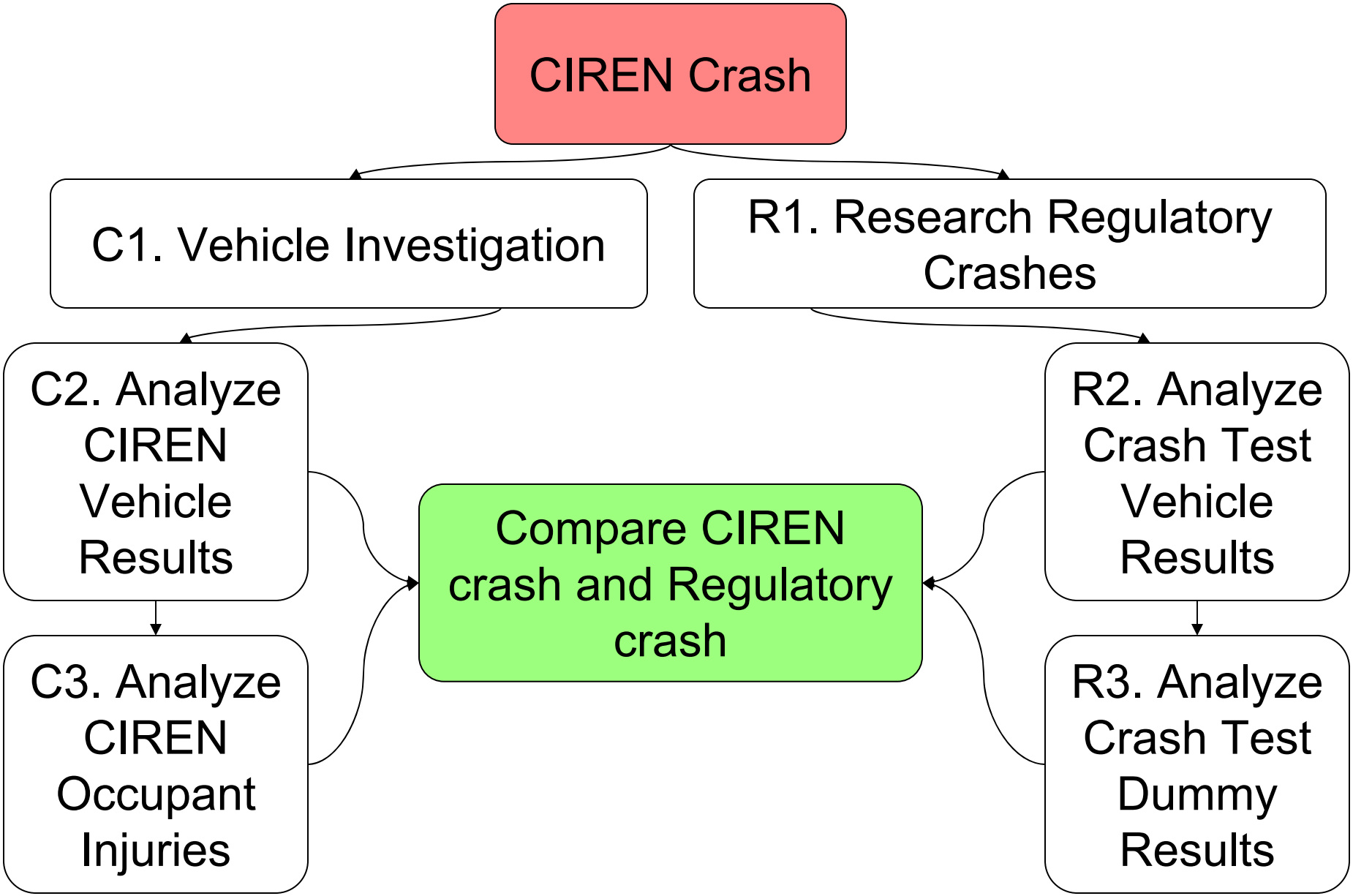
- Vehicle
- Crash
- Occupant
- Injury







Comparison Case Methods



CIREN Crash Characteristics

Vehicle Year	2005
Vehicle Make	Toyota
Vehicle Model	Rav4
PDOF	350 degrees
Crash Type	Frontal
Impacted	1999 Plymouth Grand Voyager SE
DeltaV	34.8 mph
Seat Location	Driver
Belted	Yes
Air Bag Deployment	Driver frontal airbag deployed
Fatality	No

Vehicle Safety Rating- Frontal Impact

Driver	★★★★	11 to 20 % chance of serious head and chest injury
Passenger	★★★★	11 to 20 % chance of serious head and chest injury

Finding a comparison crash test

- NHTSA NCAP database chosen because of high DeltaV frontal impact
- Checked Sisters and Clones list for vehicle year, make, model
- Searched all vehicles for Toyota Rav4 with model years between 2001 and 2005
- 3 crash tests found, 2 were frontal crashes

Viewing records starting at record 1 through 3 of 3

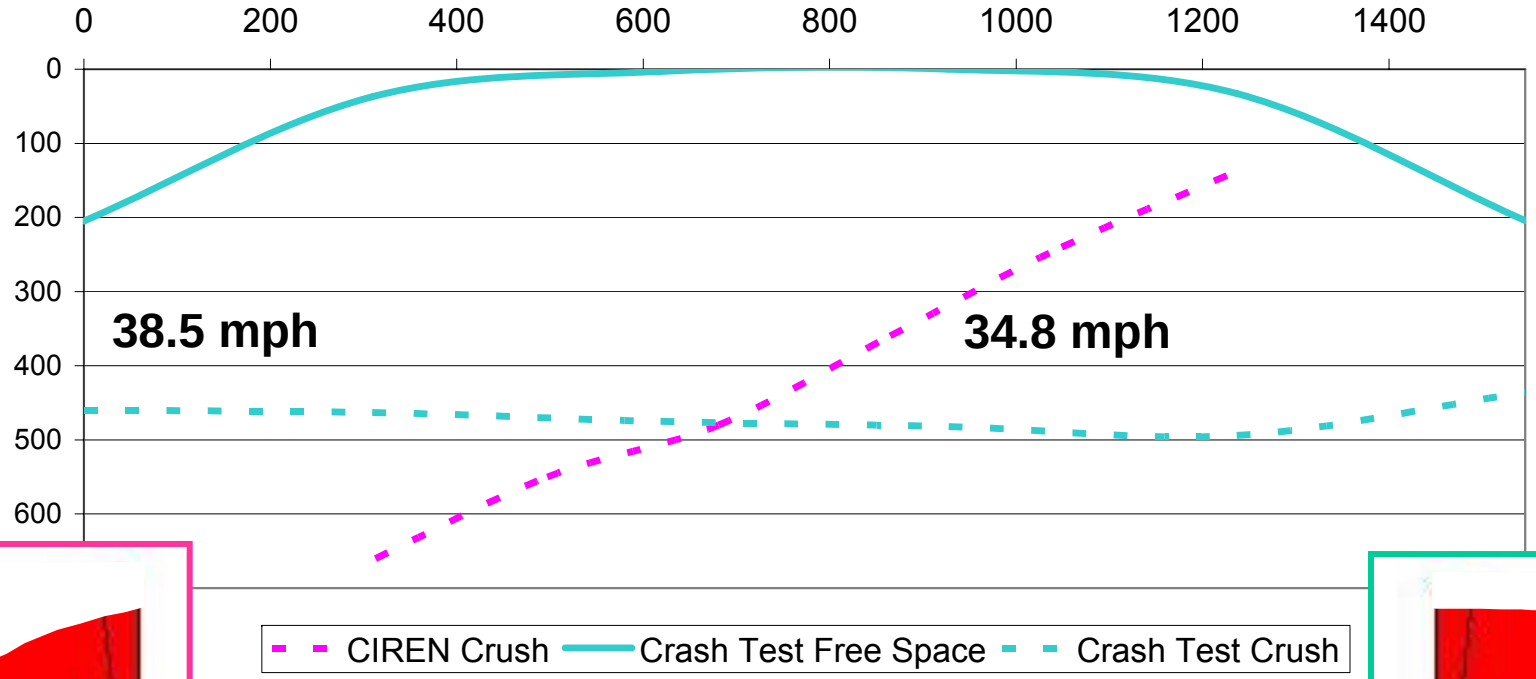
Test No.	Vehicle No.	Multimedia Files	Vehicle Make	Vehicle Model	Model Year
3613	1	Photos Reports	TOYOTA	RAV4	2001
3847	2	Photos Reports Videos	TOYOTA	RAV4	2002
4893	1	Photos Reports Videos	TOYOTA	RAV4	2004

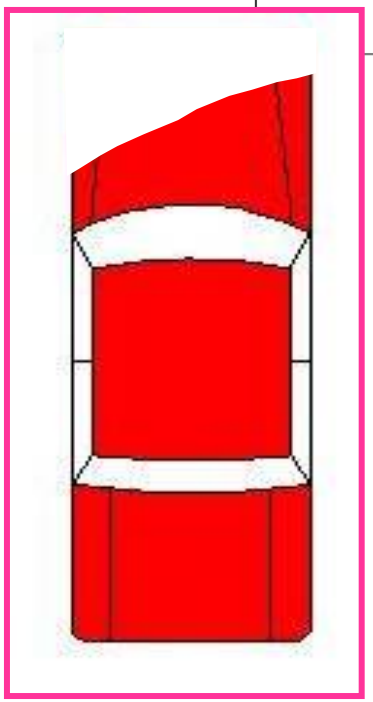
Vehicle Year and Model Interchange List, Gregory Anderson of Scalia Safety Engineering

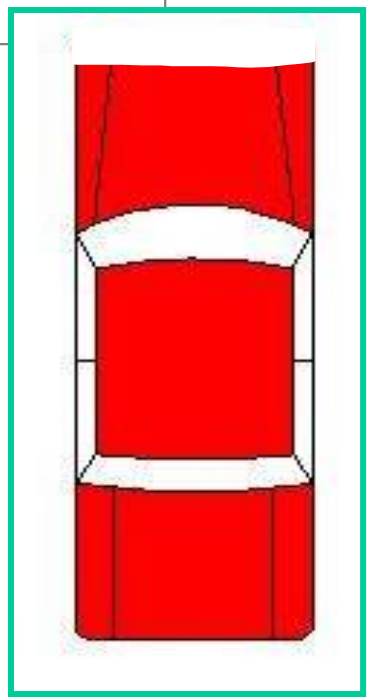
NHTSA 4893 Crash Test

Vehicle Comparison

Crush Profile Comparison







CIREN	NHTSA NCAP 4893
Max crush= 66 cm	Max crush= 48 cm

*Original car diagrams provided by MCW

Example of Similarity Score

Comparisons	CIREN	NHTSA NCAP 4893	Score (11/13)
Vehicle Year	2005	2004	1/1 (Sisters and Clones)
Vehicle Make/Model	Toyota Rav4	Toyota Rav4	1/1
PDOF	350 degrees	0 degrees	1/1 (+/- 20 degrees)
Crash Type	Frontal	Frontal	1/1
Crash Distribution	Full	Full	1/1
Maximum Crush	66 cm	48.2 cm	0/1 (+/- 10 cm)
Impacted	1999 Plymouth Grand Voyager SE	Rigid Barrier	1/1
Crash Speed	34.8 mph	38.5 mph	1/1 (+/- 10 mph)
Seat Location	Driver	Driver	1/1
Belted	Yes	Yes	1/1
Air Bag Deployment	Yes	Yes	1/1
Occupant	38 yr old Female (5' 2", 180 lbs)	HIII 50th % Male (5' 9", 172 lbs)	1/2 (incorrect height, correct weight)

Crash Test Dummy Characteristics

HIII 50th % Male

5’ 9” tall

172.3 lbs

Head: accelerometers to measure HIC

Neck: upper and lower load cells

Upper Extremity: humerus load cells

Torso: clavicle load cells, accelerometer to measure chest G’s, deflection potentiometer

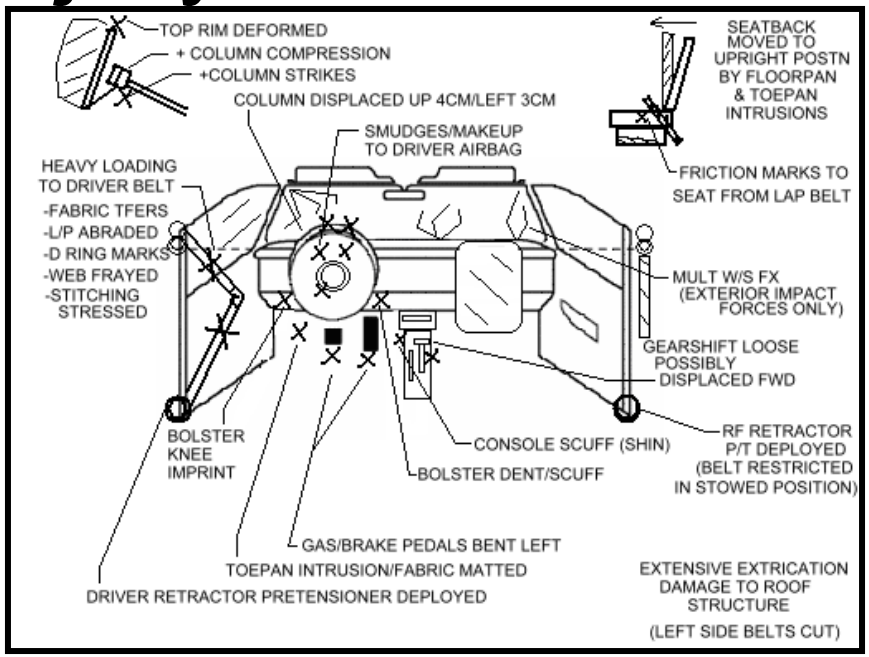
Lower Extremity: accelerometer in pelvis, femur load cells, knee slider potentiometers, tibia load cells, ankle and toe load cells

http://www.ftss.com/pcat/h3-50m-2.cfm

http://www.dentonatd.com/dentonatd/VESTA.html

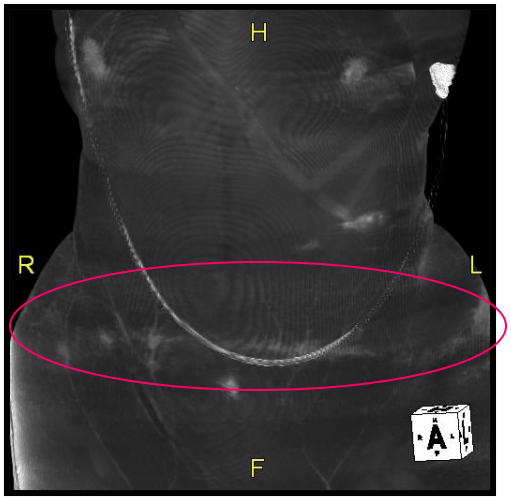
CIREN Occupant/Injury Characteristics

Gender	Female
Age	38 yr old
Height	5’ 2”
Weight	180 lb
ISS	27



Injury	AIS 3+
Left pulmonary contusion	3
Left comminuted acetabular fracture	3
Left comminuted supracondylar femur fracture	3
Right midshaft femur fracture	3
Right colonic serosal injury	3

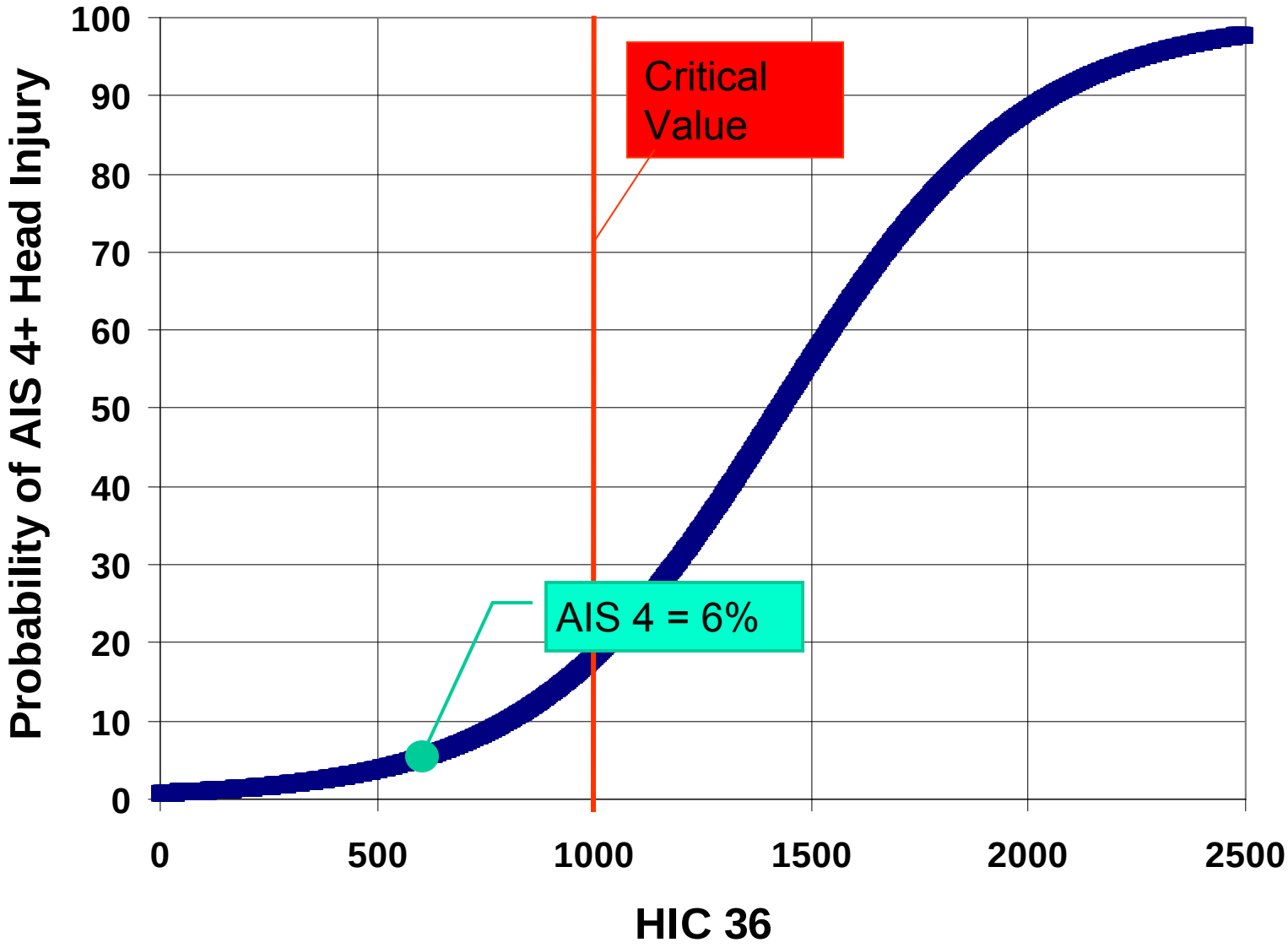
Injury	AIS 2-
Jejunum-ilieum laceration	2
C7 and T1 trans proc fx	2
Right lower leg major laceration	2
Multiple abrasions, contusions	1



Seatbelt Stripe

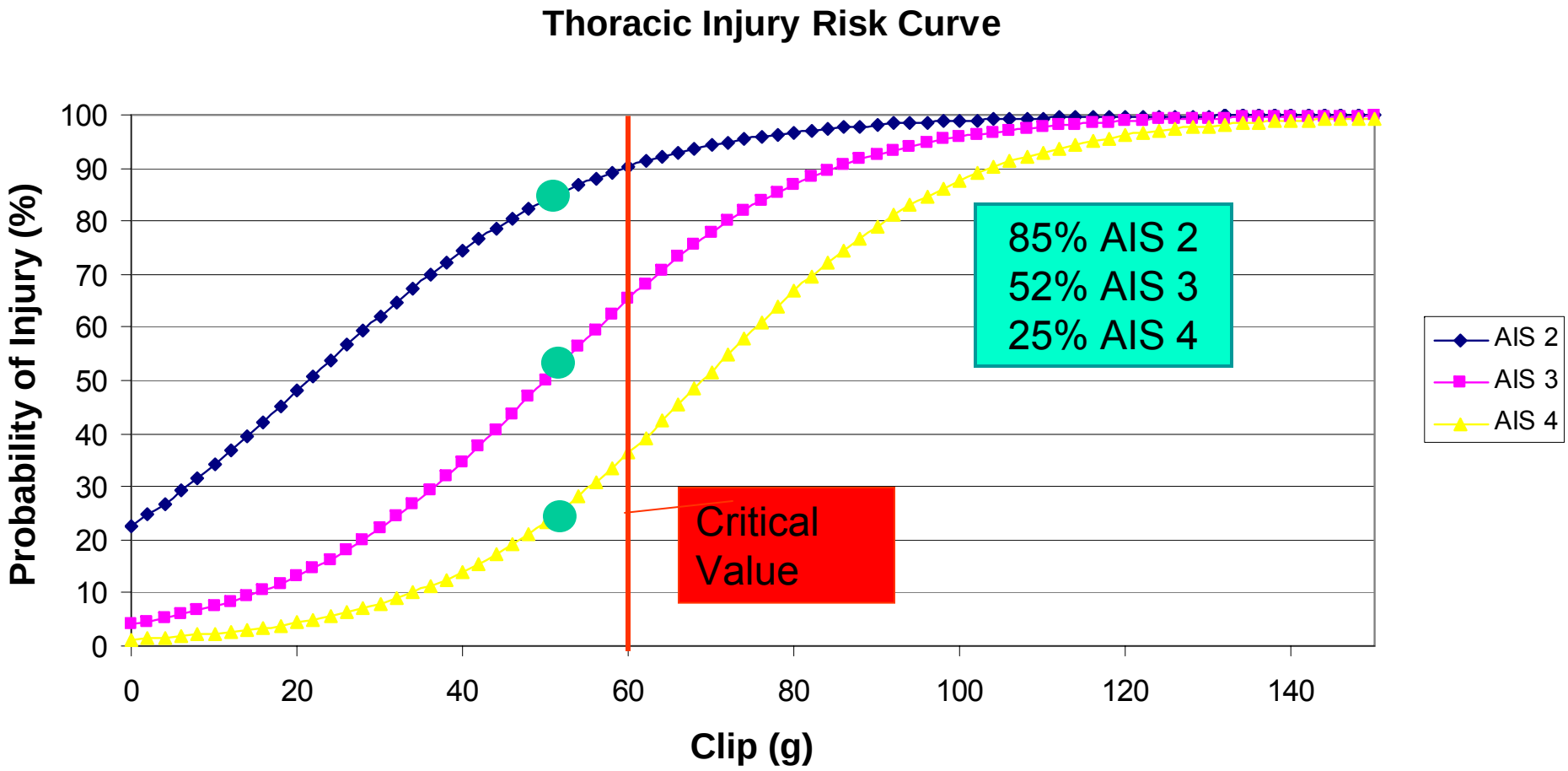
HIC36 = 636.8

CIREN Occ – no head injury



NHTSA injury risk curves

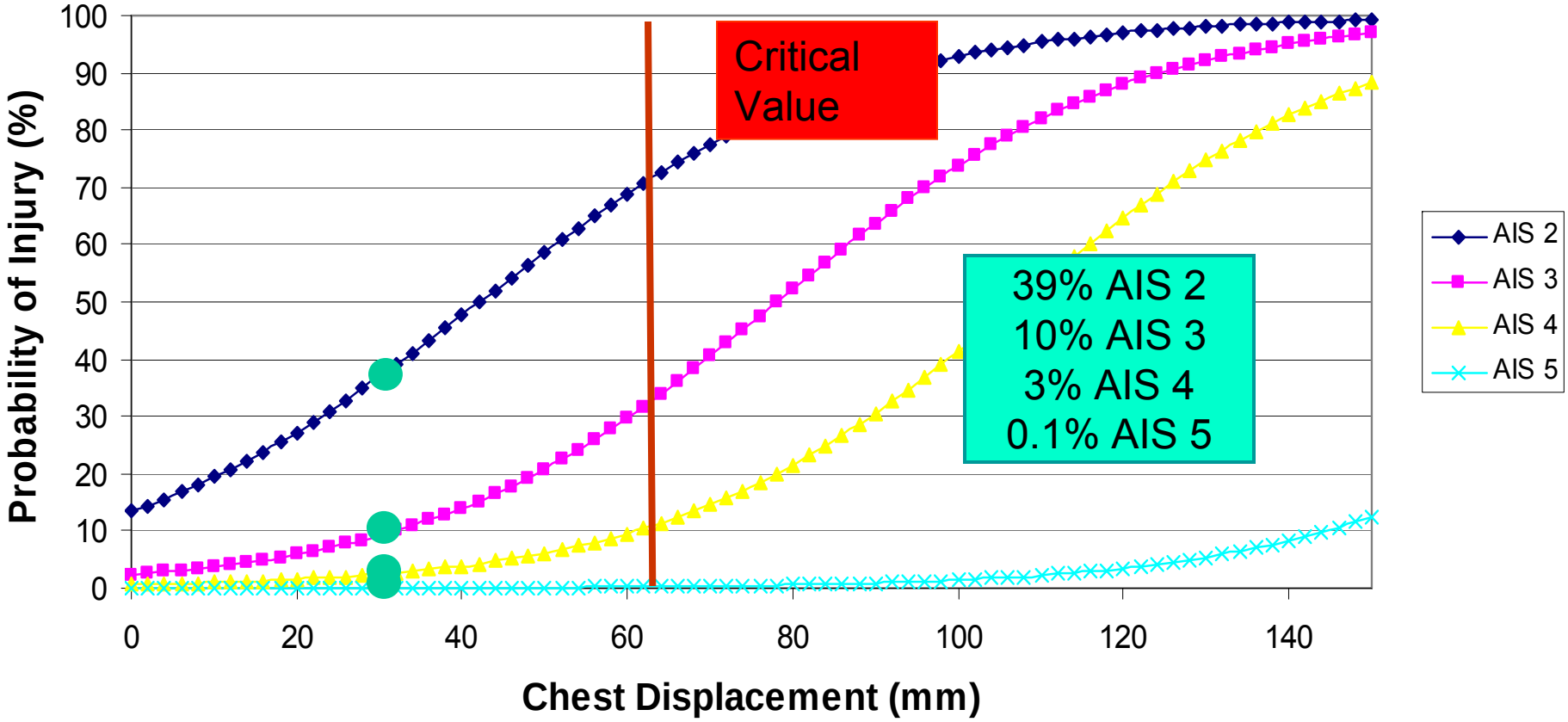
Thoracic Injury Risk = 51.6 g's



Eppinger et al. Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems- II, NHTSA 1999

CIREN Occ – AIS 3 PC

Thoracic Injury Risk = 31.8 mm

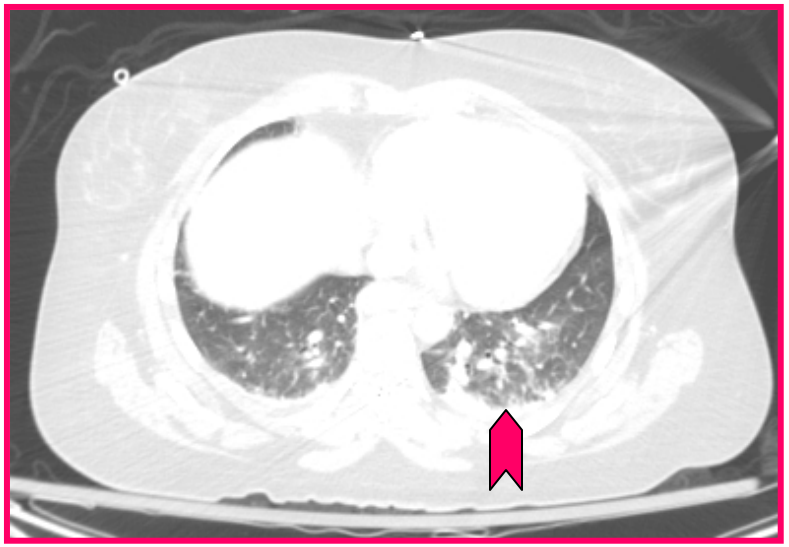


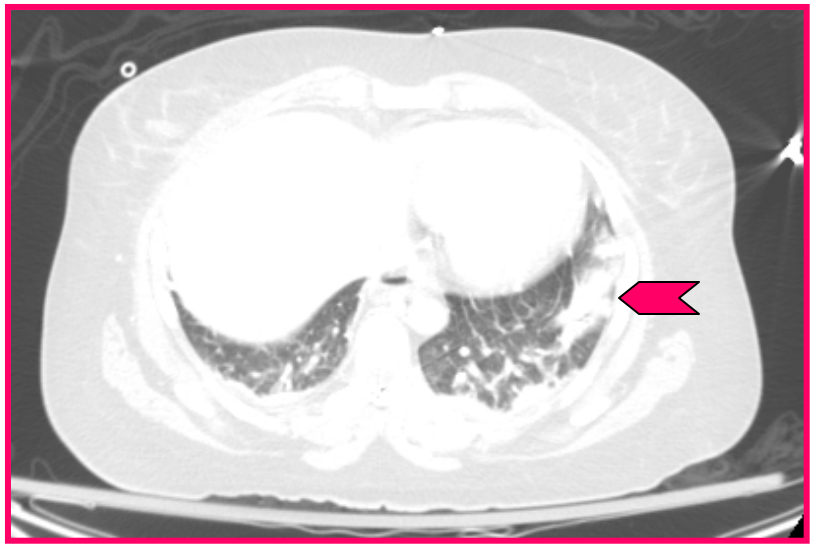
Eppinger et al. Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems- II, NHTSA 1999

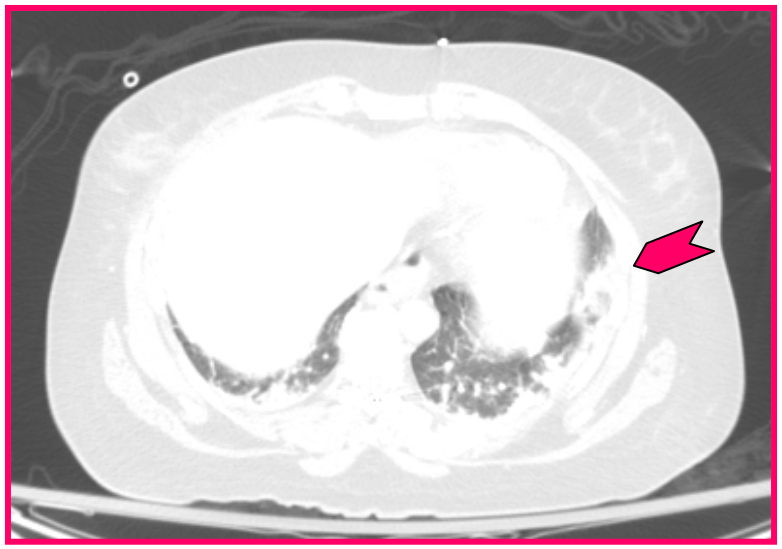
CIREN Occ – AIS 3 PC

CIREN Occupant Thoracic Injury

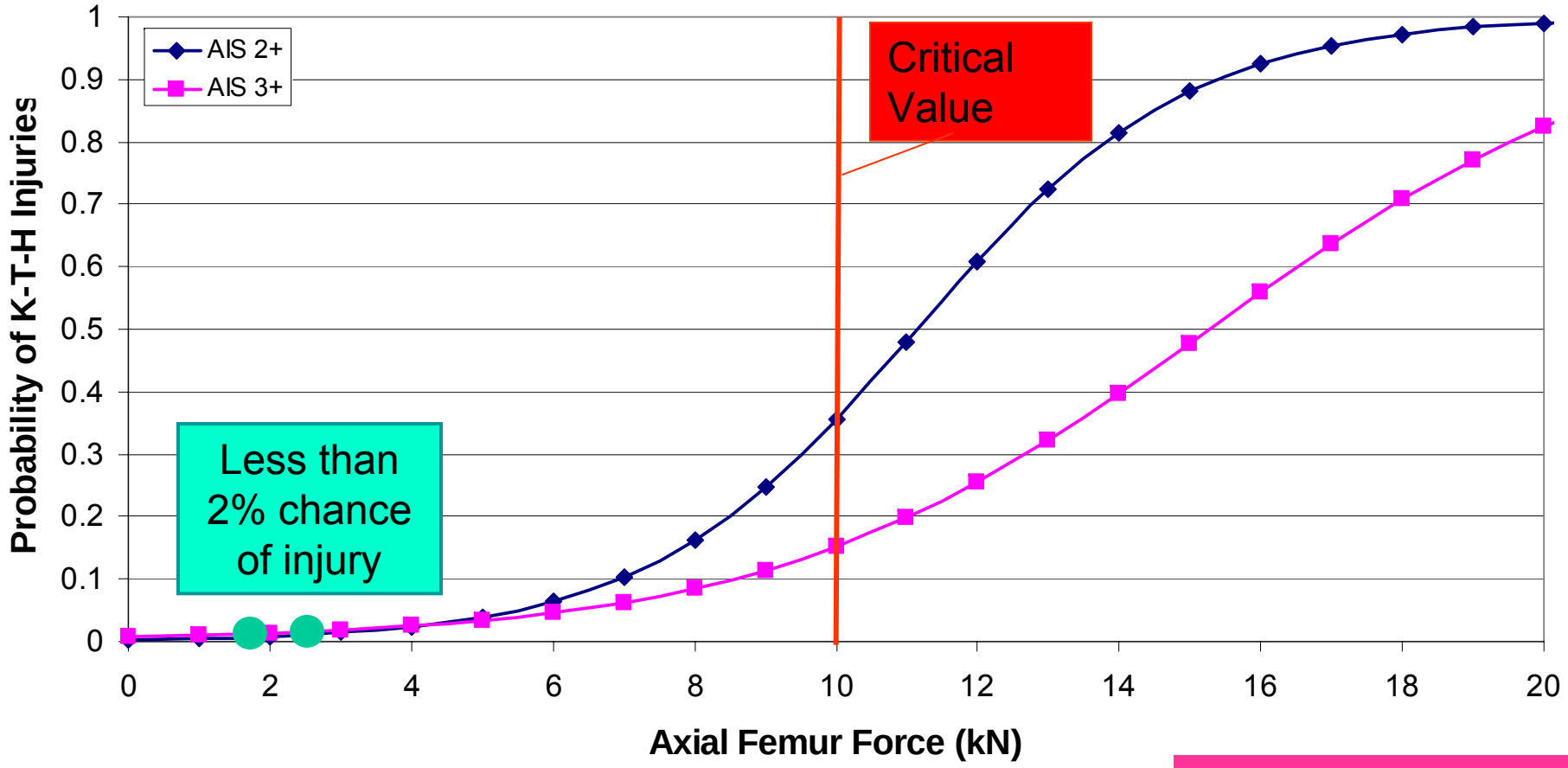
left pulmonary contusion







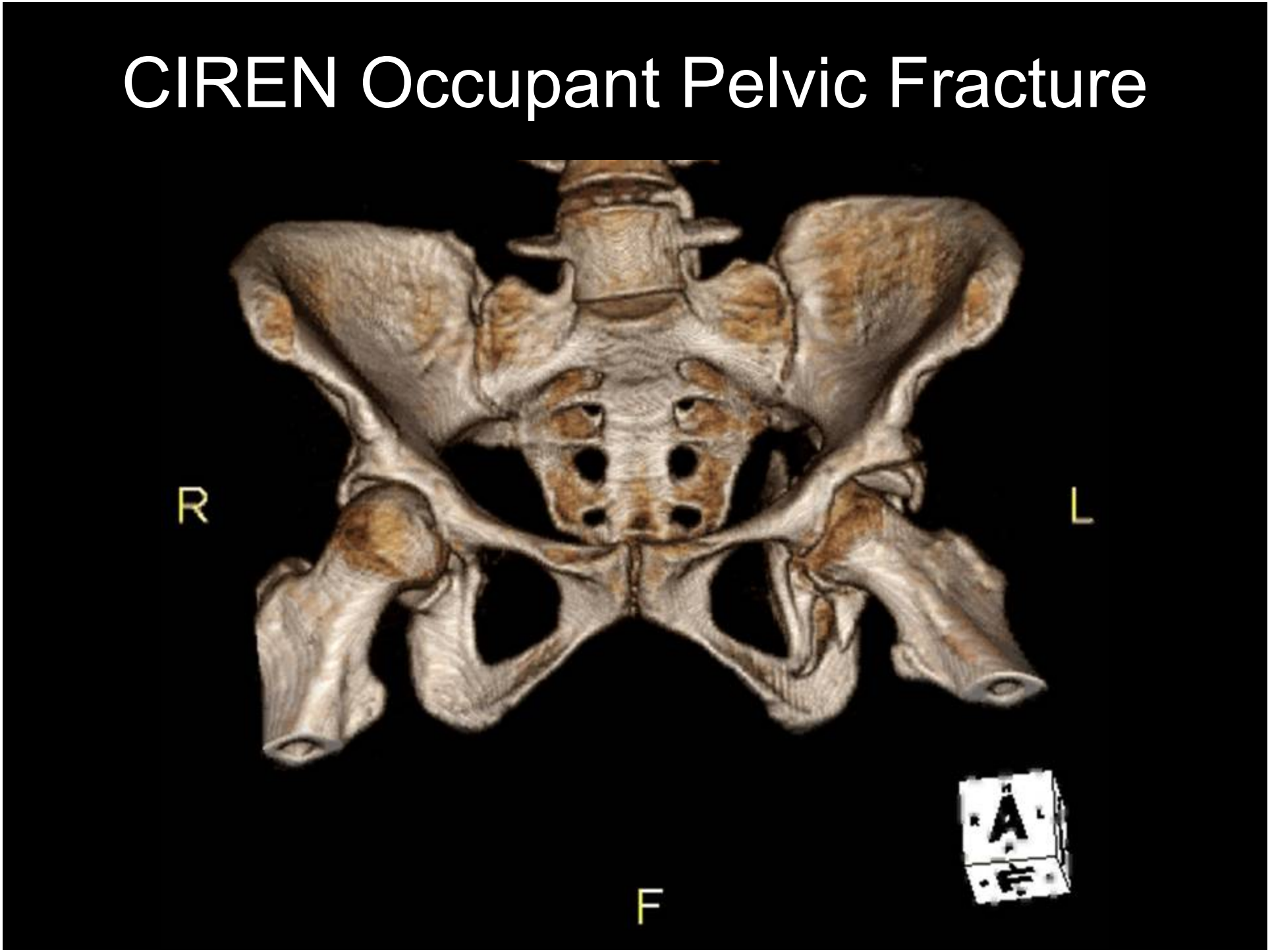
K-T-H Injury Risk
Left = 1912 N, Right = 2557 N



CIREN Occ AIS 3
Femur fractures
Acetab fractures

Kuppa et al. Lower Extremity Injuries and Associated Injury Criteria. NHTSA paper #457

CIREN Occupant Pelvic Fracture



CIREN Occupant Femur Fractures

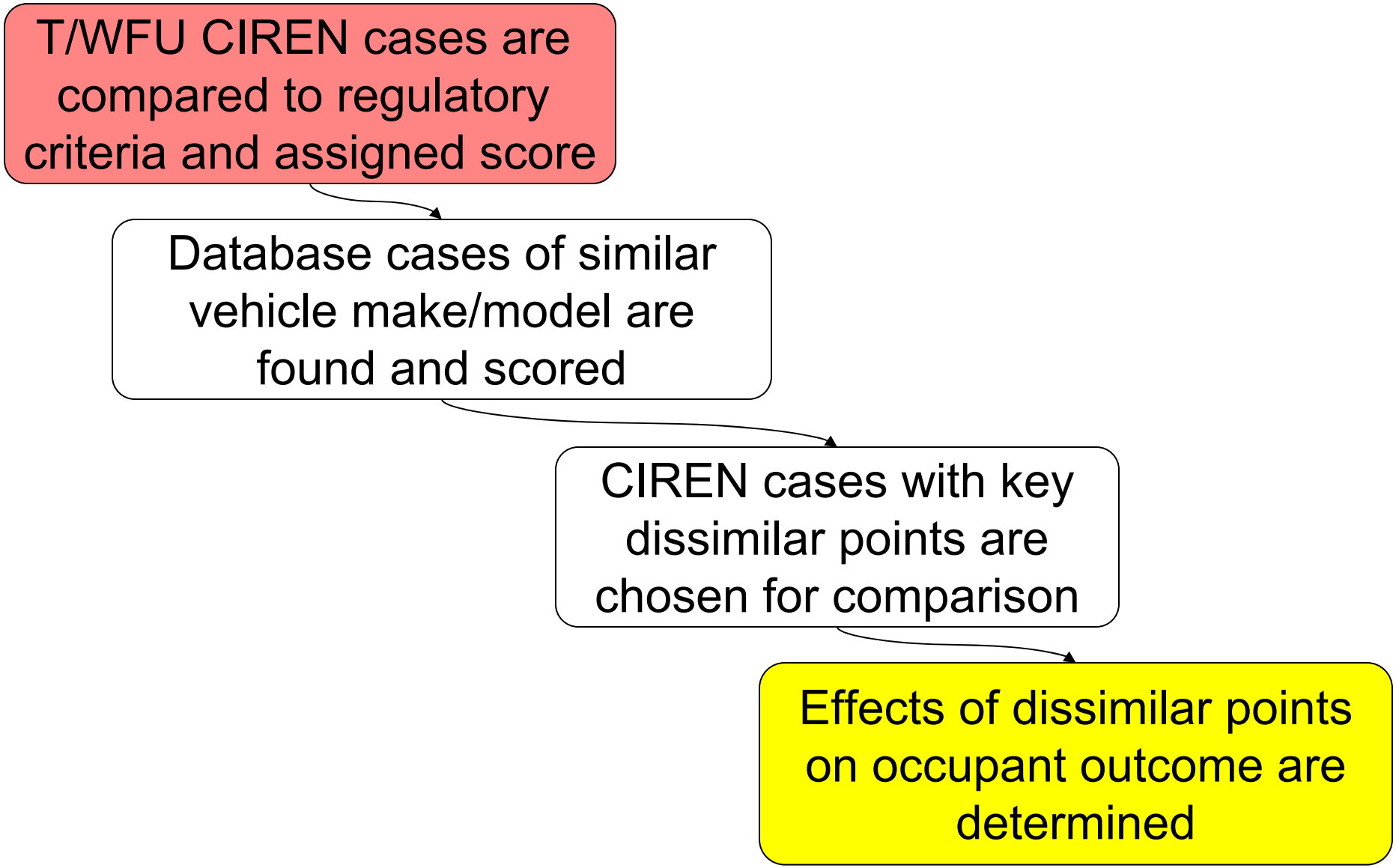
Injury metrics not currently regulated

- Abdominal injuries
  - Colonic serosal injury
  - Jejunal-ilium laceration
- Lower neck injury
  - C7, T1 trans proc fractures
- External injuries
  - Lacerations
  - Contusions (seatbelt forces)

Comparison Example Conclusion

- Similar impacts and delta v's
- CIREN case had more crush, intrusion
- Crash test dummy did not exceed critical values
- Occupant sustained serious injuries to thorax, abdomen, pelvis, and lower extremity
  - Many of which are not currently regulated ATD measurements
  - Multiple IPC's contributed to the injuries, so safety enhancements may be possible for more than one part of the vehicle

Comparison Case Methods



Regulatory Similarity (Frontal)

- 12 Regulatory criteria are matched with each of our cases.
- Matching criterion adds +1 to the 'score'
- Total score is the sum of all matching fields. (Maximum of 12)

Field	**Standard**
Vehicle Type	*Automobile*
Crash Direction	*10-2 o'Clock*
Crash Type	*Front-Distributed*
Delta-V	*>=48.2 km/h*
Airbag Deploy	*Deployed*
ISS	*ISS <=7*
Seat Location	*Front Seat*
Manual Belt Use	*Belted*
Gender	*Male or Female (not pregnant)*
Age	*> 18 years old*
Height	*175 cm (+/- 10%)*
Weight	*75 kg (+/- 10%)*

CIREN Frontal Comparison

- Each of our cases that has more than 8 Regulatory Similarities are then matched to all the cases in CIREN.
- Cases are compared based on 6 fields. (All fields must match exactly except Crash Direction)

Field
Make
Model
Crash Direction
Crash Type
Airbag
Seatbelt Use

Regulatory Similarity (Side)

- 12 Regulatory criteria are matched with each of our cases.
- Matching criterion adds +1 to the ‘score’
- Total score is the sum of all matching fields. (Maximum of 12)

Field	**Standard**
Vehicle Type	*Automobiles*
Crash Direction	*2~4 or 8~10 o'Clock*
Crash Type	*Left or Right*
Delta-V	*> Adjusted regulatory speed*
Airbag Deploy	*Deployed*
ISS	*<7*
Seat Location	*Near Side*
Manual Belt Use	*Belted*
Gender	*Male or Female (not pregnant)*
Age	*> 18 years*
Height	*175 cm (+/- 10%)*
Weight	*75 kg (+/- 10%)*

Regulatory Similarity (Side)

- Crash Type – must be near side crash
  Delta V – Adjusted for each case using momentum balance:
  - Adjusted Regulatory Speed = $\frac{\text{(Barrier mass) * Barrier speed}}{\text{(Vehicle mass + Barrier mass)}}$
  - Barrier mass = 1361 kg, Barrier speed = 35 mph (53.9 km/h)
- All other fields similar to frontal

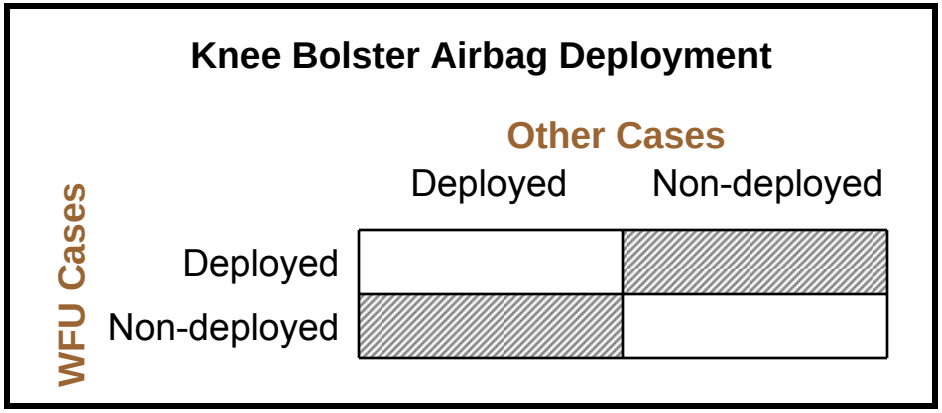
CIREN Side Airbag Comparison

- Each of our cases that has more than 6 Regulatory Similarities are then matched to all near side cases in CIREN.
- Cases are compared based on multiple fields.
- Side airbag deployment occurred in one case but not in the comparison case.

Field	Criteria
Vehicle type, crash type, gender, belt use	Exact
Crash Direction	+/- 2 o'clock
Delta V, ISS, Age, Height, Weight	+/- 10%
Side Airbag Deployment	Deployed vs. Non Deployed

Knee Bolster Airbag

- Cases with deployed knee bolster AB are pulled from CIREN
  - Our cases are matched to cases with opposite knee bolster air bag deployment cases with same make and model
  - Our cases are then compared in similarity with the similarity comparison
  - Cases with differences in knee bolster airbag deployment are compared



Case Comparisons

Frontal Impact	
842002342	38324
842003318	558022443
842004577	375029100

Seat Belt Use

WFU Cases	Other Cases: Restrained	Other Cases: Unrestrained
Restrained		**2 cases**
Unrestrained		

Occupant Age/Weight

WFU Cases	Other Cases: Young, light	Other Cases: Older, heavier
Young, light		**1 case**
Older, heavier		

Frontal Impact Comparison 1

842002342 vs. 38324

Crash/Vehicle Characteristics

842002342

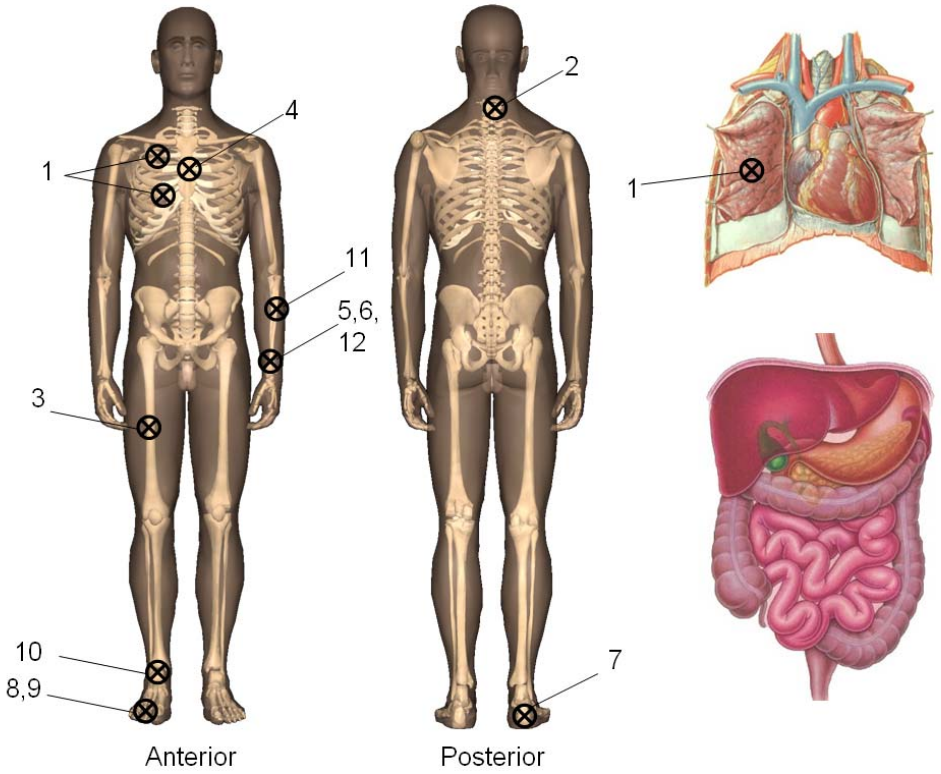
Vehicle Year	1998
Vehicle Make	Honda
Vehicle Model	Civic
Crash Direction	12 o'clock
Crash Type	Front – Distributed
Delta-V	34 km/h
Seat Location	Front, Left (driver)
Belted	Yes
Air Bag Deployment	Yes
Fatality	No

Occupant/Injury Characteristics

842002342

Gender	Male
Age	21y
Height	175 cm
Weight	66 kg
ISS	34

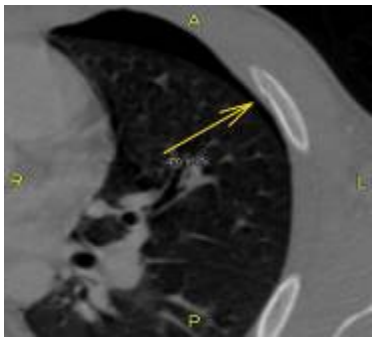
Region	No. Injuries
Head	0
Face	0
Neck	0
Chest	2
Abdomen	0
Spine	1
Upper Extremity	4
Pelvis and Lower Extremity	5



Injury Detail

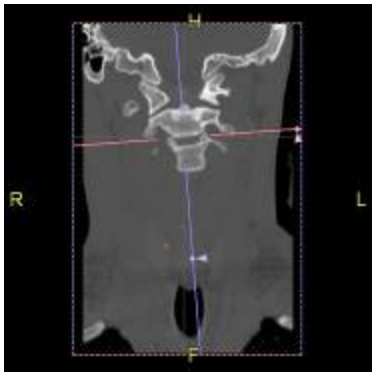
842002342

No.	AIS	Injured Body Region	Detail Injury
1	4	Thorax	Left 2nd-4th & 7th rib fractures w/ PTX
2	3	Spine	Left C2-C3 facet joint subluxation
3	3	Lower Extremity	Right comminuted femur fracture
4	2	Thorax	Sternal fracture
5	2	Upper Extremity	Left distal radius fracture
6	2	Upper Extremity	Left distal ulna fracture
7	2	Lower Extremity	Right calcaneous fracture
8	2	Lower Extremity	Right 2nd metatarsal fracture
9	2	Lower Extremity	Right 3rd metatarsal fracture
10	2	Lower Extremity	Right talus fracture
11	1	Upper Extremity	Left forearm skin abrasion
12	1	Upper Extremity	Left hand skin abrasion



4th Rib Fx
IPC: Airbag

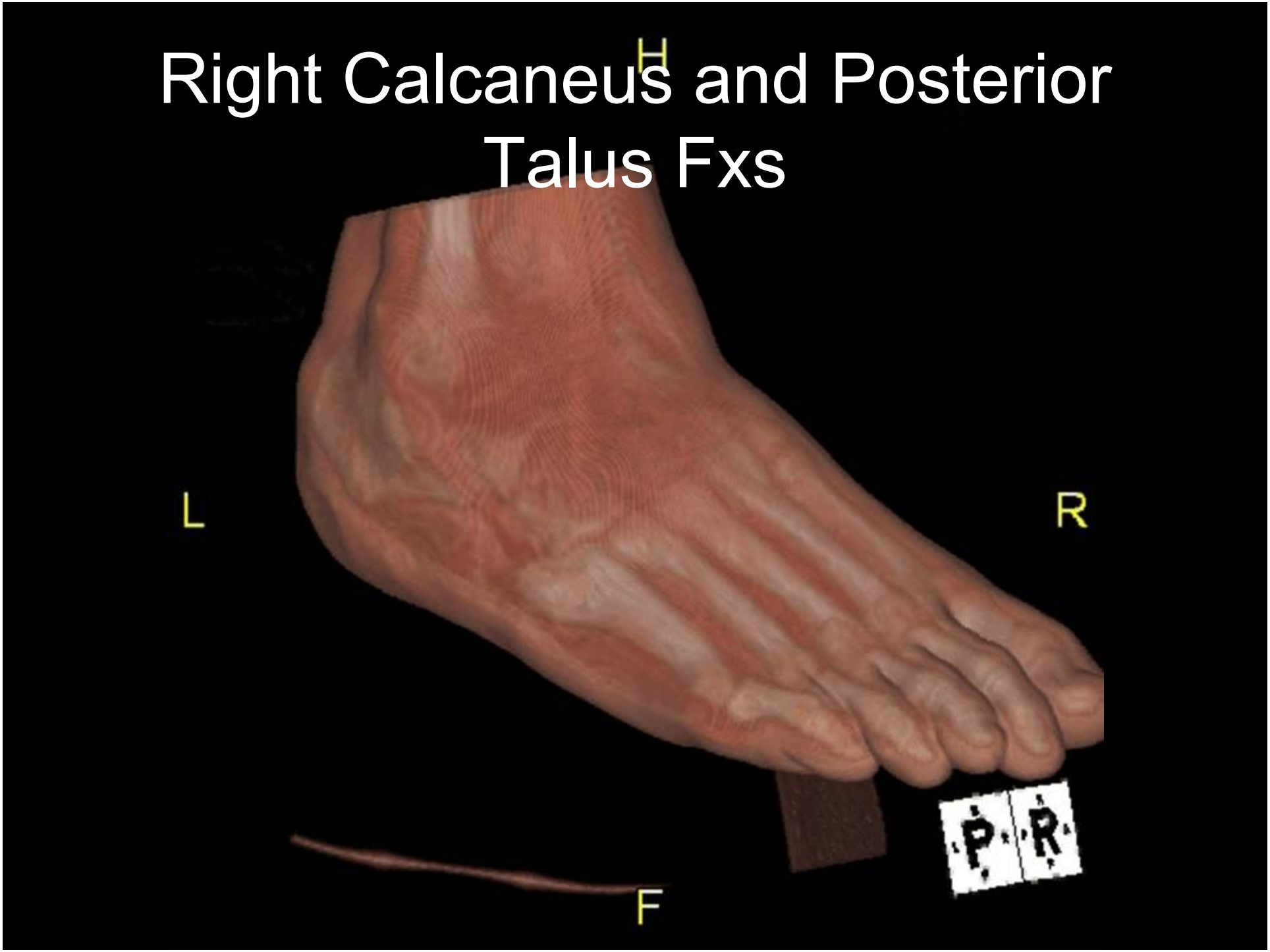
L C2-C3 facet joint subluxation
IPC: Seatbelt



Right Femur Fx
IPC: Knee bolster

Right Femur Fx

Right Calcaneus and Posterior Talus Fxs



Crash/Vehicle Characteristics

38324

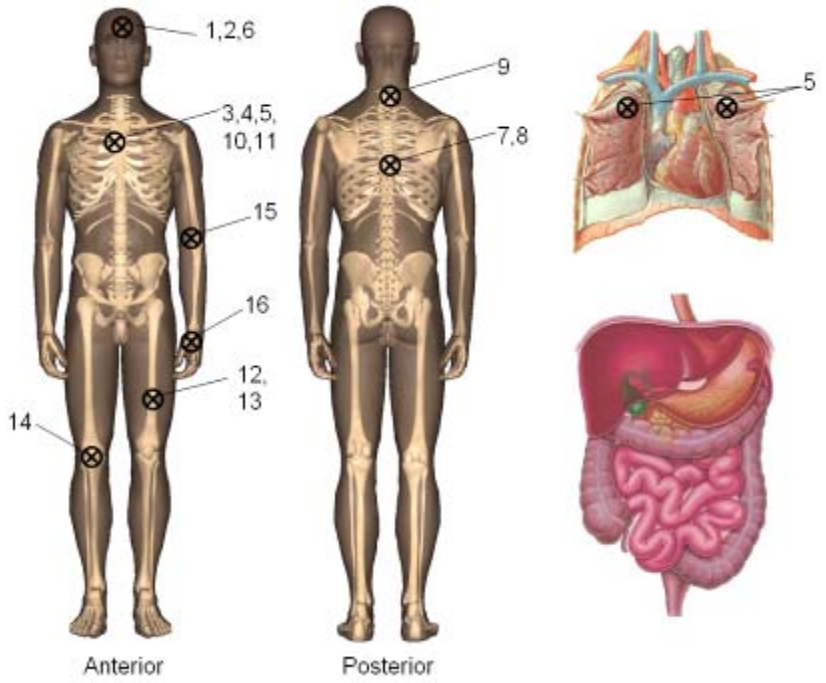
Vehicle Year	1993
Vehicle Make	Honda
Vehicle Model	Civic
Crash Direction	12 o'clock
Crash Type	Front – Distributed
Delta-V	32 km/h
Seat Location	Front, Left (driver)
Belted	No
Air Bag Deployment	Yes
Fatality	Yes

Occupant/Injury Characteristics

38324

Gender	Female
Age	47y
Height	170 cm
Weight	86 kg
ISS	42

Region	No. Injuries
Head	3
Face	0
Neck	0
Chest	5
Abdomen	0
Spine	3
Upper Extremity	2
Pelvis and Lower Extremity	3



No.	AIS	Injured Body Region	Detail Injury
1	5	Head	Brain stem injury involving hemorrhage
2	5	Head	Brain stem NFS
3	4	Thorax	Vena cava laceration major
4	4	Thorax	Right 5-8 rib fractures
5	4	Thorax	Bilateral lung contusions with or without HTX/PTX

Frontal Impact Comparison 1

Honda Civic:

Investigated Characteristic: Belt Use
Regulatory Matching Criteria:
9/12 , 8/12
Delta-V < 48.2 km/h

Similar Characteristics	842002342	38324
Delta-V (km/h)	34	32
Crash Direction	12 o'clock	12 o'clock
Crash Type	Front-Distributed	Front-Distributed
Seat Location	Front, Left	Front, Left
Airbag Deployment	Y	Y
Height (cm)	175	170

Differing Characteristics	842002342	38324
ISS	34	42
Belted	Y	N
Fatality	N	Y
Age (years)	21	47
Weight (kg)	66	86
Head Injuries	0	3 (MAIS 5) IPC: Driver AB
Chest Injuries	2 (MAIS 4) IPC: AB	5 (MAIS 4) IPC: Steering wheel

Conclusion: Belt use indicates lower ISS, non-fatality, fewer chest and head injuries.

Frontal Impact Comparison 2

Mitsubishi Galant:
8452003318 vs. 558022443
"Sister Vehicles"

Investigated Characteristics:
Occupant Weight/Age

Regulatory Matching Criteria:
11/12, 9/12
Delta-V near 48.2 km/h (regulatory speed)

Similar Characteristics	8452003318	558022443
Crash Direction	12 o'clock	11 o'clock
Crash Type	Front-Distributed	Front-Distributed
Seat Location	Front, Left	Front, Left
Belt Use	Y	Y
Airbag Deployment	Y	Y
Fatality	N	N
Height (cm)	185	180
Lower Extremity Injuries	5 (MAIS 3) IPC: Knee bolster	8 (MAIS 3) IPC: Knee bolster

Differing Characteristics	8452003318	558022443
ISS	10	27
Delta-V (km/h)	56	46
Age (years)	21	49
Weight (kg)	79	104
Head Injuries	0	2 (MAIS 3) IPC: Left A-pillar

Conclusions:

- Older and heavier occupant has higher ISS
- Both occupants had significant lower extremity injuries due to knee bolster and intruding toe pan

Frontal Impact Comparison 3

Honda Accord:
842004577 vs. 375029100
Investigated Characteristic: Belt Use

Regulatory Matching Criteria:
9/12, 8/12
Delta-V < 48.2 km/h (regulatory speed)

Similar Characteristics	842004577	375029100
Crash Direction	12 o'clock	12 o'clock
Crash Type	Front-Center	Front-Center
Seat Location	Front, Left	Front, Left
Airbag Deployment	Y	Y
Fatality	N	N
Weight (kg)	72	75

Differing Characteristics	842004577	375029100
ISS	11	21
Belt Use	Y	N
Delta-V (km/h)	42	30
Height (cm)	165	178
Age (years)	47	19
Abdominal Injuries	0	1 (AIS 4) IPC: Steering wheel rim

Conclusions: Belt use indicates lower ISS even though the occupant was older and delta-v was higher. Abdominal injuries were seen only in the unbelted occupant and were attributed to the steering wheel rim.

Case Comparisons

Side Impact	
842005510	852153529
842005511	484028652
842012140	385103760
842012173	142053939

Side Airbag Deployment

WFU Cases	Other Cases: Deployed	Other Cases: Non-deployed
Deployed		**1 case**
Non-deployed	**3 cases**	

Side Impact Comparison 1

84205510 vs. 852153529

Crash/Vehicle Characteristics

84205510

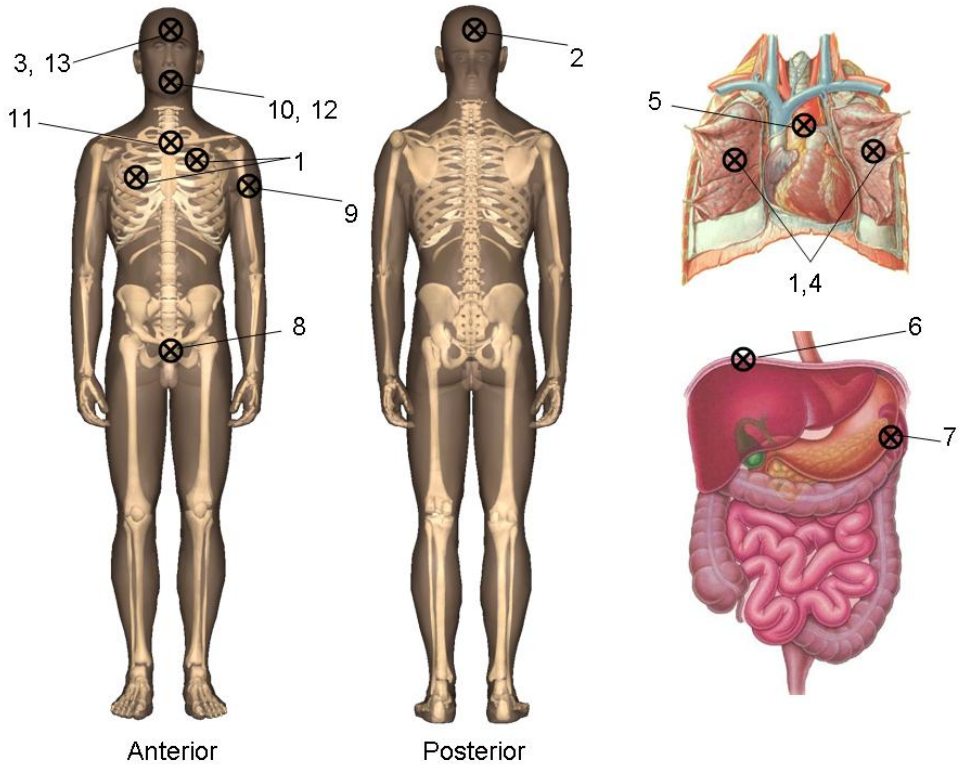
Vehicle Year	1999
Vehicle Make	Honda
Vehicle Model	Civic/CRX/Del Sol
Crash Direction	9 o'clock
Crash Type	Left – Front & Center
Delta-V	38 km/h
Seat Location	Front, Left (driver)
Belted	Yes
Side Air Bag Deployment	No
Fatality	No

Occupant/Injury Characteristics

84205510

Gender	Male
Age	30y
Height	182 cm
Weight	88 kg
ISS	66

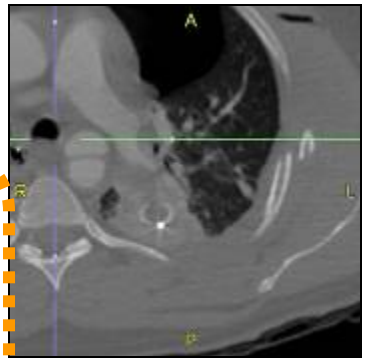
Region	No. Injuries
Head	3
Face	2
Neck	0
Chest	5
Abdomen	1
Spine	0
Upper Extremity	1
Pelvis and Lower Extremity	1



Injury Detail

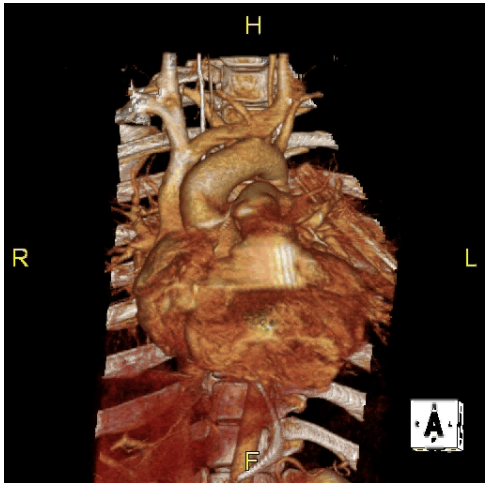
84205510

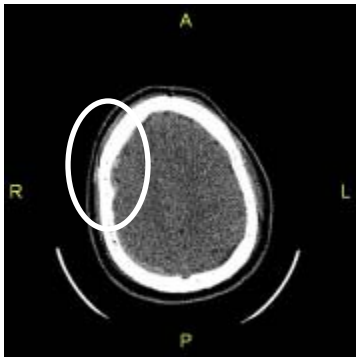
No.	AIS	Injured Body Region	Detail Injury
1	5	Thorax	Bilateral rib fractures w/ HTX/PTX
2	5	Head	Diffuse axonal brain injury
3	4	Head	Small subdural hematoma
4	4	Thorax	Bilateral lung contusion
5	4	Thorax	Thoracic aorta injury
6	4	Thorax	Ruptured diaphragm
7	3	Abdomen	Spleen laceration
8	3	Pelvis	Pubic symphysis fracture
9	2	Upper Extremity	Left proximal humerus fracture
10	2	Face	Comminuted left mandibular fracture
11	2	Thorax	Sternum fracture
12	1	Face	Right mandibular fracture
13	1	Head	Scalp laceration minor



L Rib fx
IPCs: B-pillar, driver door
R rib fxs
IPC: Seatbelt

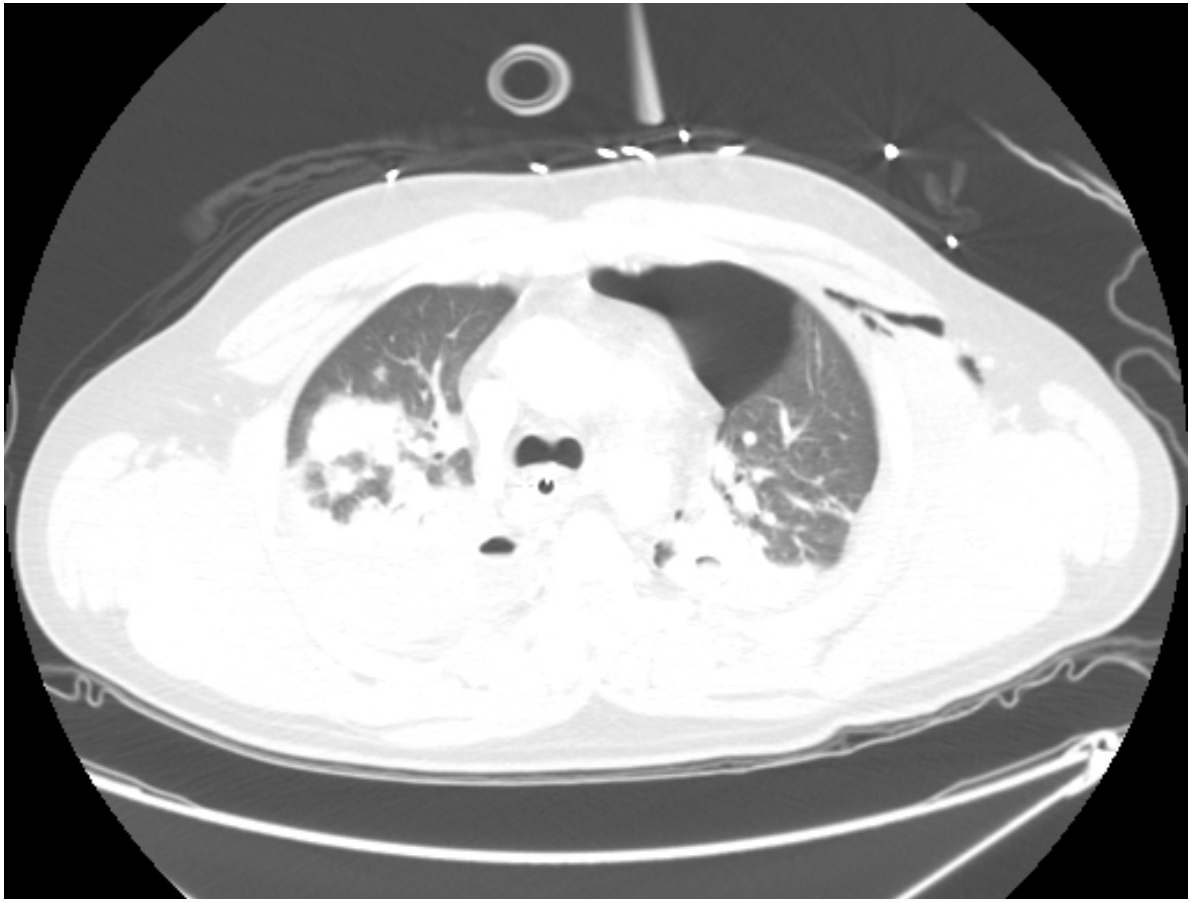
Thoracic aortic injury
IPC:B-pillar, driver door



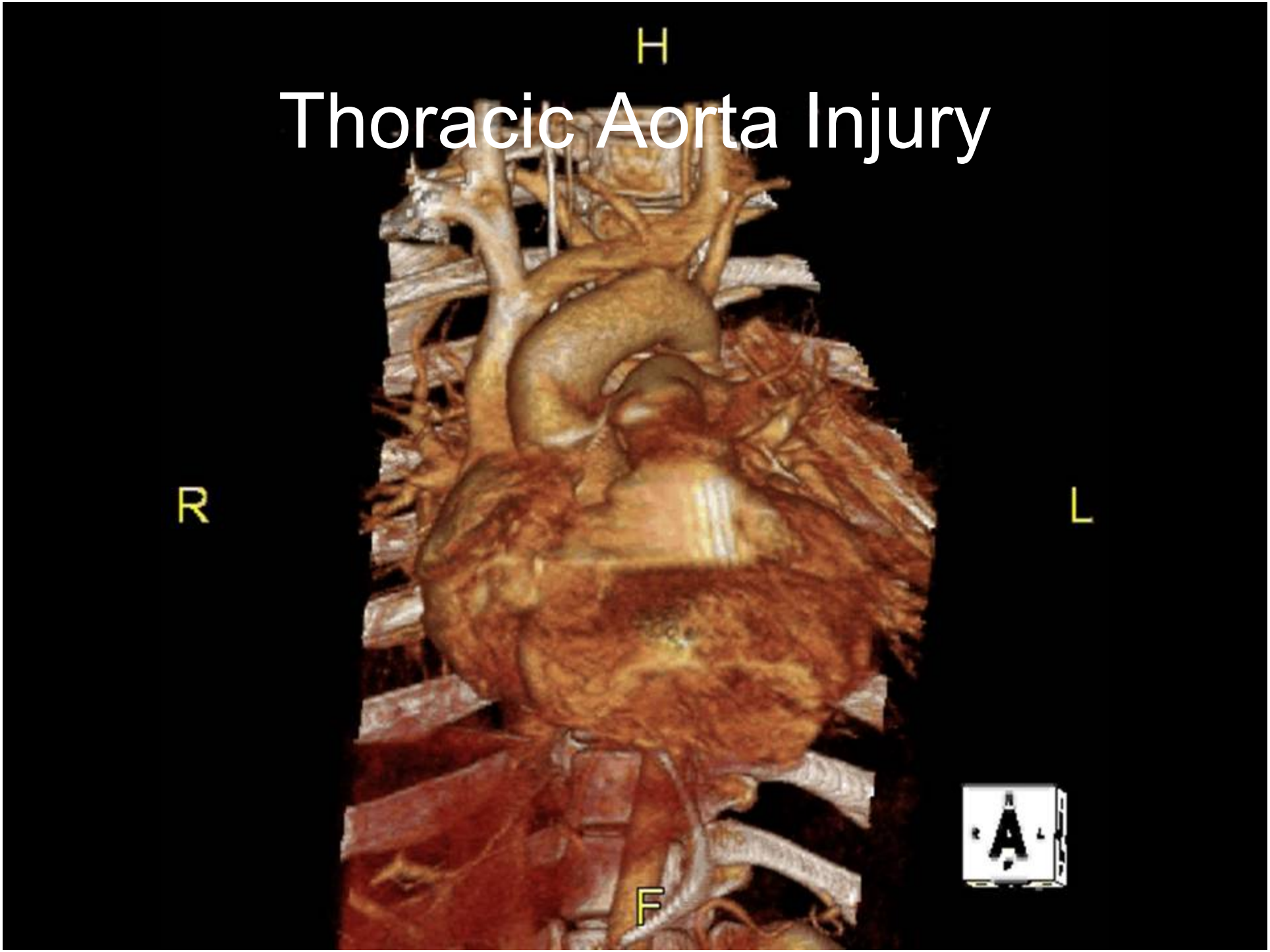


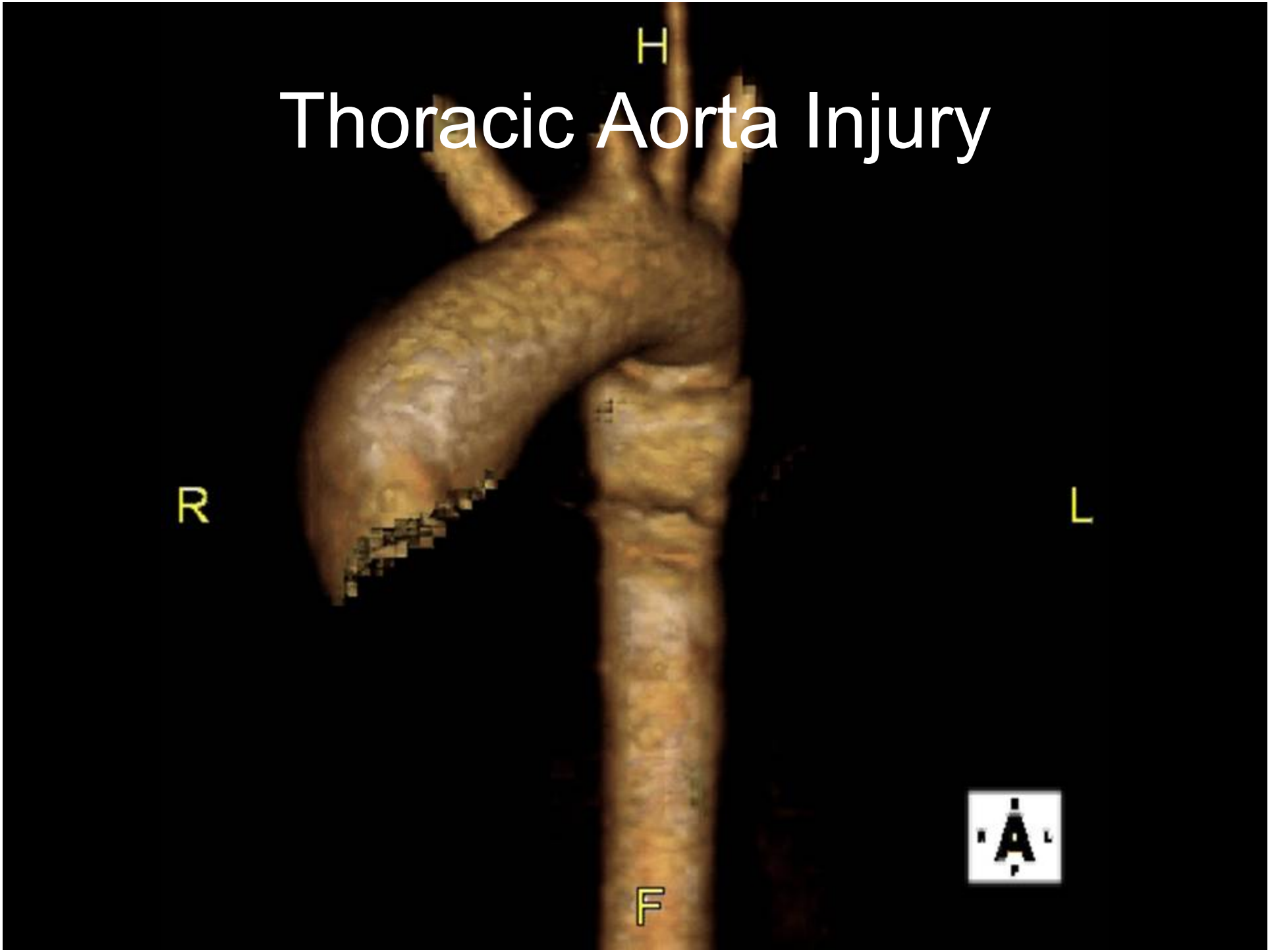
Small subdural hematoma
IPC: B-pillar

Bilateral Rib Fx with PTX, HTX



Thoracic Aorta Injury





Thoracic Aorta Injury

Crash/Vehicle Characteristics

852153529

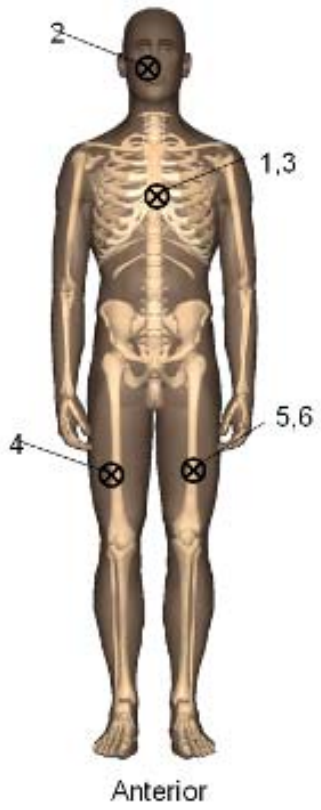
Vehicle Year	2008
Vehicle Make	Honda
Vehicle Model	Civic/CRX/Del Sol
Crash Direction	9 o'clock
Crash Type	Left – Front & Center
Delta-V	48 km/h
Seat Location	Front, Left (driver)
Belted	Yes
Side Air Bag Deployment	Yes – Side Curtain and Seatback Mounted
Fatality	No

Occupant/Injury Characteristics

852153529

Gender	Male
Age	78y
Height	173 cm
Weight	77 kg
ISS	17

Region	**No. Injuries**
Head	0
Face	1
Neck	0
Chest	2
Abdomen	0
Spine	0
Upper Extremity	0
Pelvis and Lower Extremity	3

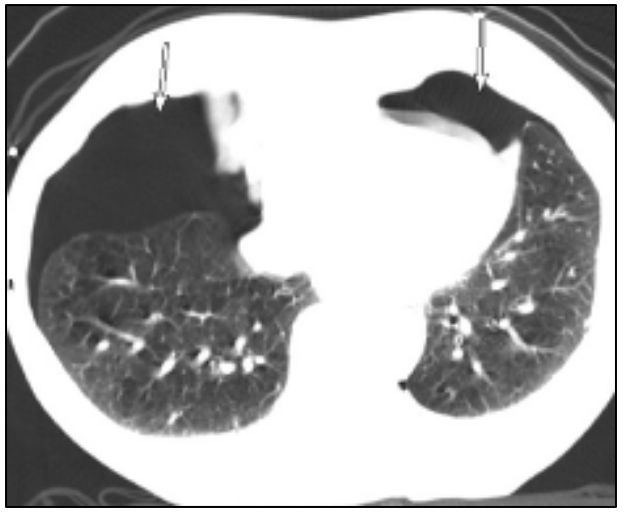


Injury Detail

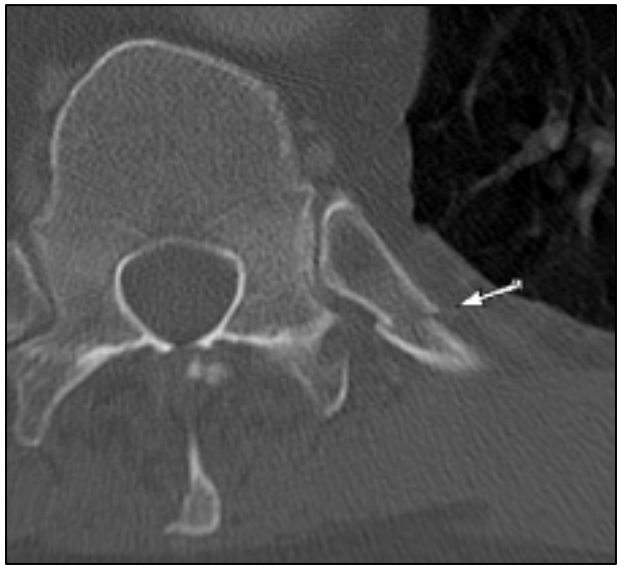
852153529

No.	AIS	Injured Body Region	Detail Injury
1	4	Thorax	Bilateral rib cage fractures: 8 ribs on left side and <= 3 ribs on right side with HTX/PTX
2	1	Face	Left eyelid abrasion
3	1	Abdomen	Chest skin contusion
4	1	Lower Extremity	Right thigh skin contusion
5	1	Lower Extremity	Left thigh skin contusion
6	1	Lower Extremity	Left thigh and lower leg skin contusion

HTX/PTX
IPC: Side AB



Rib fx
IPC: Side AB



Side Impact Comparison 1

Honda Civic:
84205510 vs. 852153529
Investigated Characteristic:
Side Airbag Deployment

Regulatory Matching Criteria:
9/12, 11/12
Delta-V > 27.6 km/h (regulatory speed)
Case Similarity Matching Criteria: 8/12

Similar Characteristics	84205510	852153529
Delta-V (km/h)	38	48
Crash Direction	9 o'clock	9 o'clock
Crash Type	Left-Front & Center	Left-Front & Center
Seat Location	Front, Left	Front, Left
Belt Use	Y	Y
Fatality	N	N
Height (cm)	182	173

Differing Characteristics	84205510	852153529
ISS	66	17
Side Airbag Deployment	N	Y
Age (years)	30	78
Weight (kg)	88	77
Chest Injuries	4 (MAIS 5) IPCs: Driver door, Seatbelt	1 (AIS 4) IPC: Side AB
Head Injuries	3 (MAIS 5) IPC: B-pillar	0

Conclusions:

- Side and Curtain AB resulted in lower ISS although occupant was elderly and Delta-V was higher.
- Lower incidence of chest and head injuries in crash with deployed side AB and curtain.

Side Impact Comparison 2

Honda Accord:
842005511 vs. 484028652

Investigated Characteristics:
Side Airbag Deployment, Belt Use

Regulatory Matching Criteria:
9/12, 9/12
Delta-V > 28.4 km/h (regulatory speed)
Case Similarity Matching Criteria: 7/12

Similar Characteristics	842005511	484028652
Delta-V (km/h)	44	45
Crash Direction	2 o'clock	2 o'clock
Crash Type	Right-Side Center	Right-Front & Center
Seat Location	Front, Right	Front, Right
Height (cm)	167	170

Differing Characteristics	842005511	484028652
ISS	57	66
Fatality	N	Y
Side Airbag Deployment	Y	N
Belt Use	N	Y
Age (years)	26	49
Weight (kg)	54	95
# of AIS 3+ Injuries	5	12
Vehicle Year	2006	1989

Conclusions:

- Higher ISS and fatality in belted occupant with no side and curtain AB
- High ISS, but no fatality in unbelted occupant with side and curtain AB, intrusion contributed to injuries
- Improvements to the vehicle structure from 1989 to 2006 may have contributed to lower ISS and fatality rates in newer model

Side Impact Comparison 3

Chevrolet Aveo:
842012140 vs. 385103760

Investigated Characteristic:
Side Airbag Deployment

Regulatory Matching Criteria:
9/12 , 11/12
Delta-V near 30.1 km/h (regulatory speed)
Case Similarity Matching Criteria: 7/12

Similar Characteristics	842012140	385103760
Delta-V (km/h)	29	33
Crash Direction	9 o'clock	9 o'clock
Crash Type	Left-Distributed	Left-Front & Center
Seat Location	Front, Left	Front, Left
Belt Use	Y	Y
Fatality	N	N
Weight (kg)	63	73

Differing Characteristics	842012140	385103760
ISS	34	14
Side Airbag Deployment	N	Y
Age (years)	69	45
Height (cm)	185	163
Chest Injuries	3 (MAIS 4) IPCs: Driver door, L interior surface	1 (AIS 1)

Conclusions:

- Side AB deployment resulted in lower ISS.
- Increased incidence of chest injuries due to the driver door and interior surface in crash with no side AB.

Side Impact Comparison 4

Acura MDX:
842012173 vs. 142053939

Investigated Characteristic:
Side Airbag Deployment

Regulatory Matching Criteria:
9/12 , 8/12
Delta-V near 21.9 km/h (regulatory speed)
Case Similarity Matching Criteria: 7/12

Similar Characteristics	842012173	142053939
Delta-V (km/h)	21	25
Crash Direction	2 o'clock	2 o'clock
Crash Type	Right-Front & Center	Right-Front & Center
Seat Location	Front, Right	Front, Right
Belt Use	Y	Y
Fatality	N	N
Weight (kg)	69	67
Height (cm)	172	157

Differing Characteristics	842012173	142053939
ISS	34	17
Side Airbag Deployment	N	Y
Age (years)	57	39
Chest Injuries	1 (MAIS 4) IPC: B-pillar, Door	0

Conclusions:

- Side AB deployment resulted in lower ISS
- Higher incidence of chest injuries due to B-pillar and door in crash with no side AB

Case Comparisons

Knee Bolster AB Comparisons	
842012175	27567
842003320	857098982

Knee Bolster Airbag Deployment

Other Cases

WFU Cases	Deployed	Non-deployed
Deployed		**1 case**
Non-deployed	**1 case**	

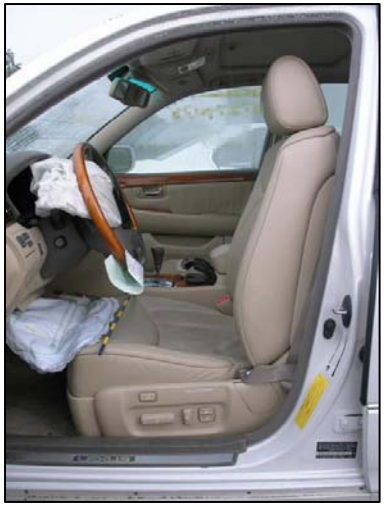
Knee Bolster Airbag Comparison 1

842012175 vs. 27567

Crash/Vehicle Characteristics

842012175

Vehicle Year	2004
Vehicle Make	Lexus
Vehicle Model	LS400
Crash Direction	12 o'clock
Crash Type	Front – Distributed
Delta-V	47 km/h
Seat Location	Front, Left (driver)
Belted	Yes
Knee Bolster Air Bag Deployment	Yes
Fatality	No

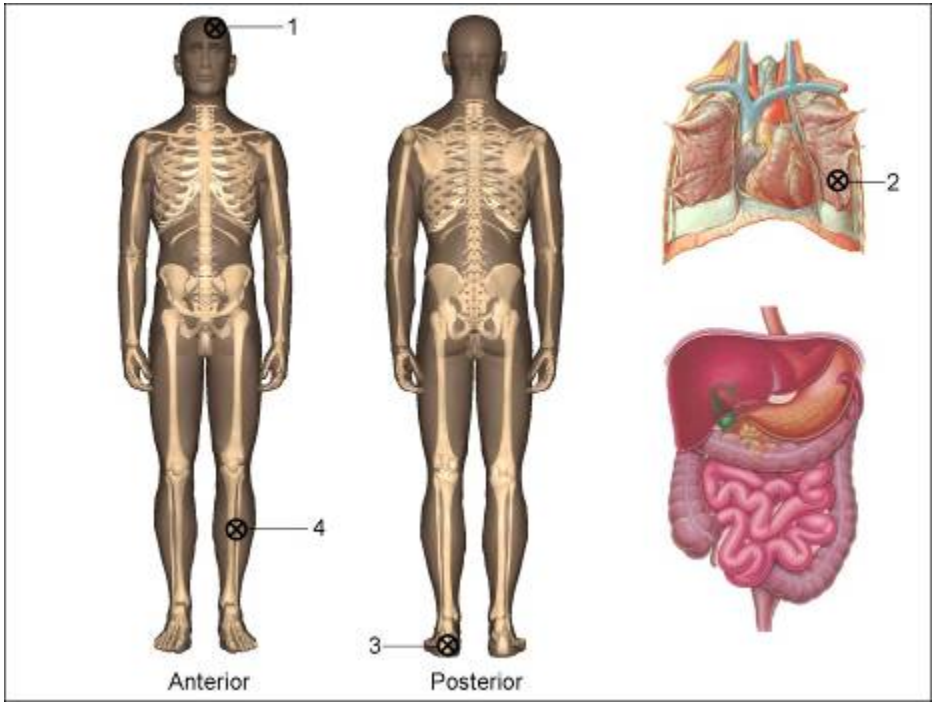


Occupant/Injury Characteristics

842012175

Gender	Female
Age	55y
Height	158 cm
Weight	49 kg
ISS	22

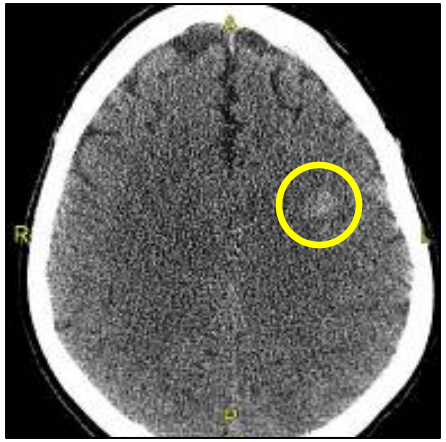
Region	No. Injuries
Head	1
Face	0
Neck	0
Chest	1
Abdomen	0
Spine	0
Upper Extremity	0
Pelvis and Lower Extremity	2



Injury Detail

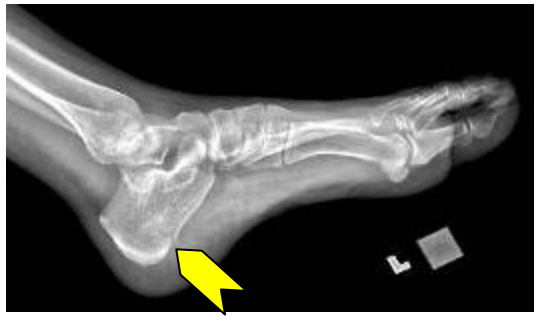
842012175

No.	AIS	Injured Body Region	Detail Injury	IPC
1	3	Head	Left frontal lobe contusion	Driver Airbag
2	3	Thorax	Left pneumothorax	Seatbelt
3	2	Lower Extremity	Left comminuted calcaneous fracture	
4	1	Lower Extremity	Left anterior mid leg abrasion	



Left frontal lobe contusion

Left pneumothorax



Left comminuted calcaneous fx

Crash/Vehicle Characteristics

27567

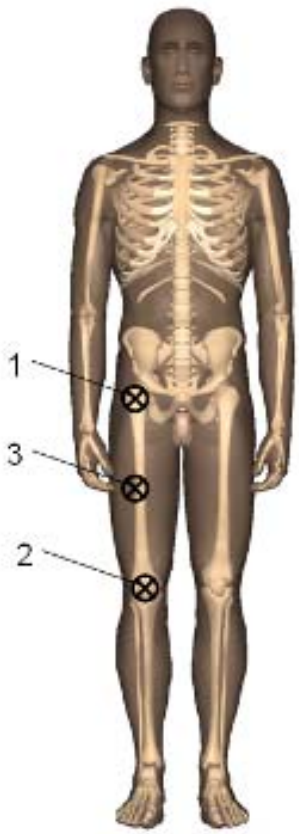
Vehicle Year	1995
Vehicle Make	Lexus
Vehicle Model	LS400
Crash Direction	12 o'clock
Crash Type	Front – Distributed
Delta-V	71 km/h
Seat Location	Front, Left (driver)
Belted	Yes
Knee Bolster Air Bag Deployment	No
Fatality	No

Occupant/Injury Characteristics

27567

Gender	Male
Age	49y
Height	163 cm
Weight	67 kg
ISS	9

Region	**No. Injuries**
Head	0
Face	0
Neck	0
Chest	0
Abdomen	0
Spine	0
Upper Extremity	0
Pelvis and Lower Extremity	3



Anterior


Posterior

Injury Detail

27567

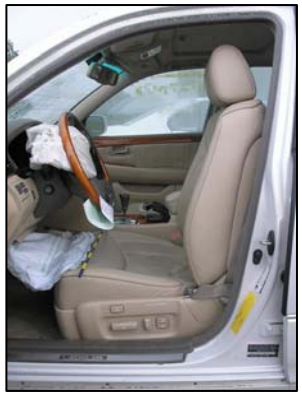
No.	AIS	Injured Body Region	Detail Injury	Injury Source
1	3	Lower Extremity	R femoral neck fracture	Knee bolster
2	3	Lower Extremity	R femoral supracondylar fracture	Knee bolster
3	3	Lower Extremity	R femoral shaft fracture	Knee bolster

R femoral neck fx

R femoral supracondylar fx

R femoral shaft fx

Knee Bolster Airbag Comparison 1



Lexus LS400:
842012175 vs. 27567
Investigated Characteristic:
Knee Bolster Airbag Deployment

Regulatory Matching Criteria:
10/12 , 9/12
Delta-V >/≈ 48.2 km/h (regulatory speed)
Case Similarity Matching Criteria: 5/12

Similar Characteristics	842012175	27567
Crash Direction	12 o'clock	12 o'clock
Crash Type	Front – Distributed	Front - Distributed
Seat Location	Front, Left	Front, Left
Belt Use	Y	Y
Fatality	N	N

Differing Characteristics	842012175	27567
ISS	22	9
Delta-V (km/h)	47	71
Knee Bolster AB Deployment	Y	N
Weight (kg)	49	67
Height (cm)	158	168
Age (years)	55	49
Lower Extremity Injuries	1 (AIS 2)	3 (AIS 3) IPC: Knee bolster

Conclusions: Lower extremity injuries less severe in crash with deployed knee bolster AB

Knee Bolster Airbag Comparison 2

Dodge Caravan:
842003320 vs. 857098982

Investigated Characteristic:
Knee Bolster Airbag Deployment

Regulatory Matching Criteria:
7/12 , 8/12
Delta-V < 48.2 km/h (regulatory speed)
Case Similarity Matching Criteria: 9/12

Similar Characteristics	842003320	857098982
Delta-V (km/h)	39	30
Crash Direction	12 o'clock	12 o'clock
Crash Type	Front – Left	Front – Left & Center
Seat Location	Front, Left	Front, Left
Belt Use	Y	Y
Fatality	N	N
Weight (kg)	87	91
Age (years)	45	43

Differing Characteristics	842003320	857098982
ISS	17	10
Knee Bolster AB Deployment	N	Y
Height (cm)	172	160
Femur fx	1 (AIS 3) IPC: Knee bolster	0
Fibula/tibia fx	1 (AIS 3) IPC: Floor panel, parking brake	1 (AIS 3) IPC: Pedal
Foot fx	0	1 (AIS 2) IPC: Toe pan

Conclusions: Higher ISS and femur fx due to knee bolster in crash with no knee bolster AB. Other lower extremity injuries seen in both occupants due to different components (floor panel, foot pedals, toe pan).

Conclusions/Recommendations

- Frontal Impact Comparisons
  - Belt use indicates lower ISS (2 comparisons)
  - Numerous frontals, opportunities for comparisons
- Side Impact Comparisons
  - Confirmations of side airbag effectiveness in severe cases
- Knee Bolster Airbag Comparisons
  - KB airbag shows beneficial effects reducing femur fx, but could trade this for Low Ext Fx

- Developed method for comparison of safety systems or other characteristics in all crash modes.
- Identified a method for similarity scoring with regulatory conditions.
- Method can be used to study effects of differing characteristics while controlling for desired characteristics.

Comparison Summary

- As more cases are entered into the CIREN database, there will be more opportunities for comparison.
- CIREN is a useful database for investigating similar crashes and advanced safety systems.
- By performing these comparisons, we can investigate improved safety systems in vehicles and specific differences between cases leading to improved occupant outcome.

Thank you!

National Highway Traffic Safety Administration

CIREN Network

Toyota Motor Corporation

Work was performed for the Crash Injury Research and Engineering Network (CIREN) Project at Wake Forest University School of Medicine in cooperation with the United States Department of Transportation/National Highway Traffic Safety Administration (USDOT/NHTSA). Funding has been provided by Toyota Motor North America Inc. under Cooperative Agreement Number DTNH22-05-H-61001. Views expressed are those of the authors and do not represent the views of any of the sponsors or NHTSA.

Contact: Dr. Joel D. Stitzel (jstitzel@wfubmc.edu)

TOYOTA

Toyota – Wake Forest University School of Medicine CIREN Center

WAKE FOREST UNIVERSITY SCHOOL of MEDICINE