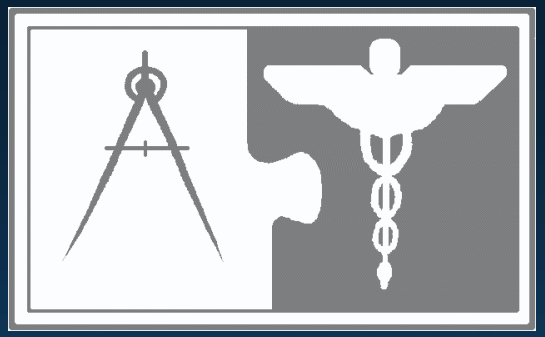
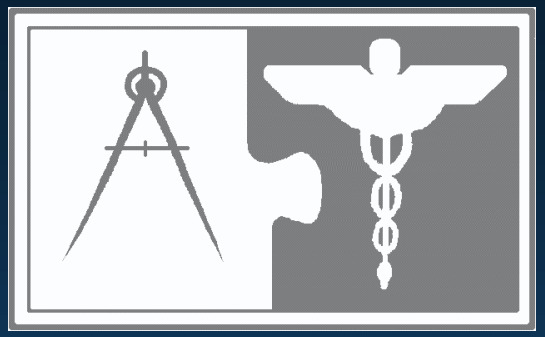
Mercedes~Benz CIREN Center
UAB Center for Injury Sciences

http://injuryscience.hs.uab.edu



Case Summary

- 24 year old restrained female driver of a 1995 Saturn SL1
- Heavy damage noted to vehicle, extrication time of 10 minutes
- Awake, disoriented at the scene
- Complained of left chest wall pain and left shoulder pain



Case Summary

- Elevated left hemi-diaphragm suspicious for diaphragmatic injury
- Exploratory laparotomy revealed grade IV splenic laceration with associated hemi-diaphragmatic injury
- Uncomplicated post-operative course

CRASH DATA

- CASE VEHICLE — 1995 Saturn SL1
- OTHER VEHICLE — 1991 Ford Escort
- TIME OF CRASH — 10:30 a.m. / Daylight
- ROAD CONDITIONS — Dry / Clear
- SPEED — 30 mph
- AVOIDANCE — None
- RESTRAINTS — Lap & Shoulder Belt
  Deployed Airbag

VEHICLE SPECIFICATIONS

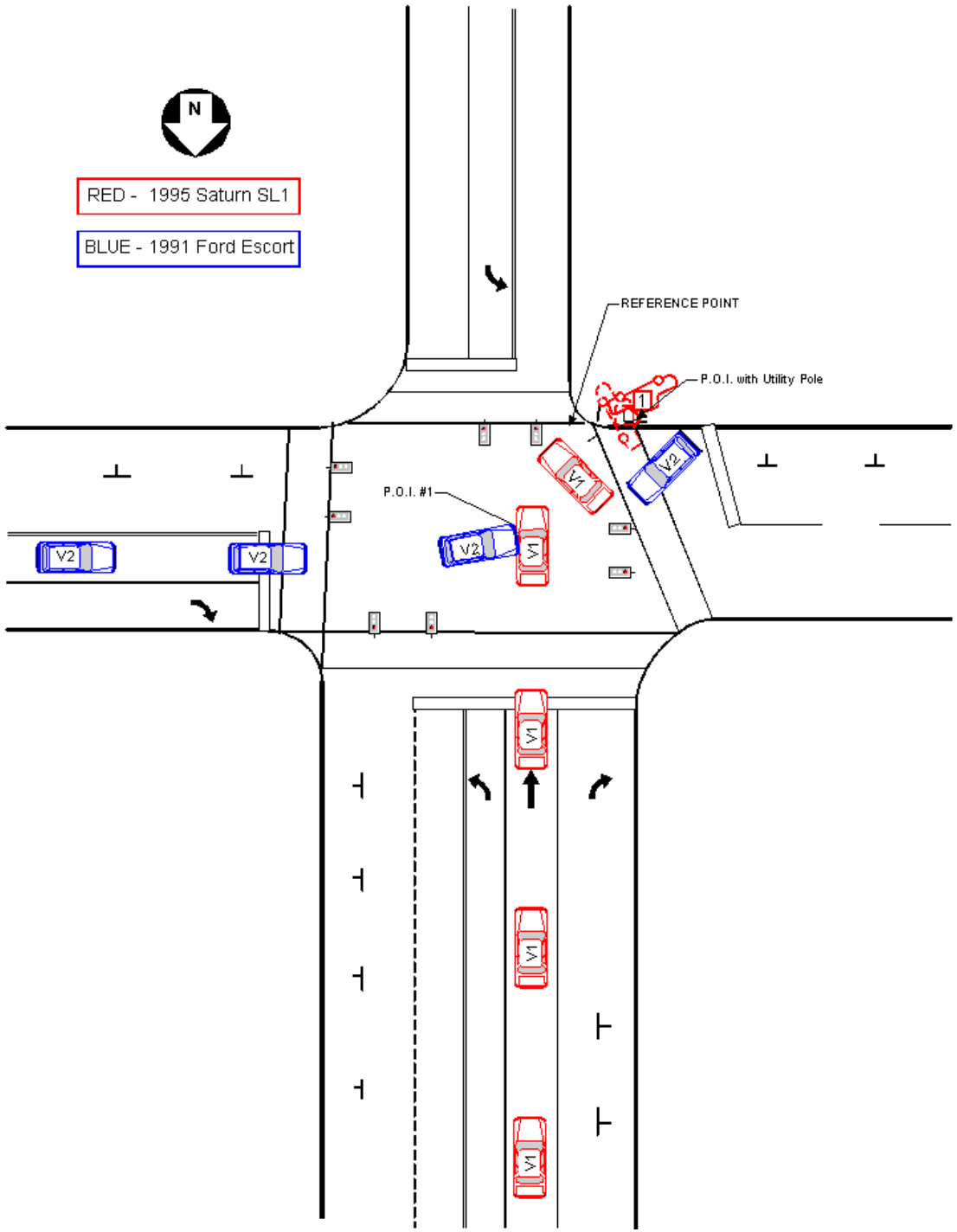
- WHEELBASE 260 cm. / 102 in.
- OVERALL LENGTH 448 cm. / 176 in.
- OVERALL WIDTH 172 cm. / 68 in.
- CURB WEIGHT 1054 kg. / 2324 lb.
- PDOF (PRINCIPAL DIRECTION OF FORCE) -60 degrees
- CDC (COLLISION DEFORMATION CLASS.) 10LYEW3
- DELTA V 26 km / 16 mph

INTRUSIONS

• LF Door Panel	20 cm. / 8 in.	Lateral
• Left Sill	20 cm. / 8 in.	Lateral
• Left ‘B’ Pillar	9 cm. / 4 in.	Lateral
• Left Kick Panel	8 cm. / 3 in.	Lateral
• LF Seat Cushion	11 cm. / 4 in.	Lateral
• LF Seatback	11 cm. / 4 in.	Lateral
• LR Door Panel	18 cm. / 7 in.	Lateral

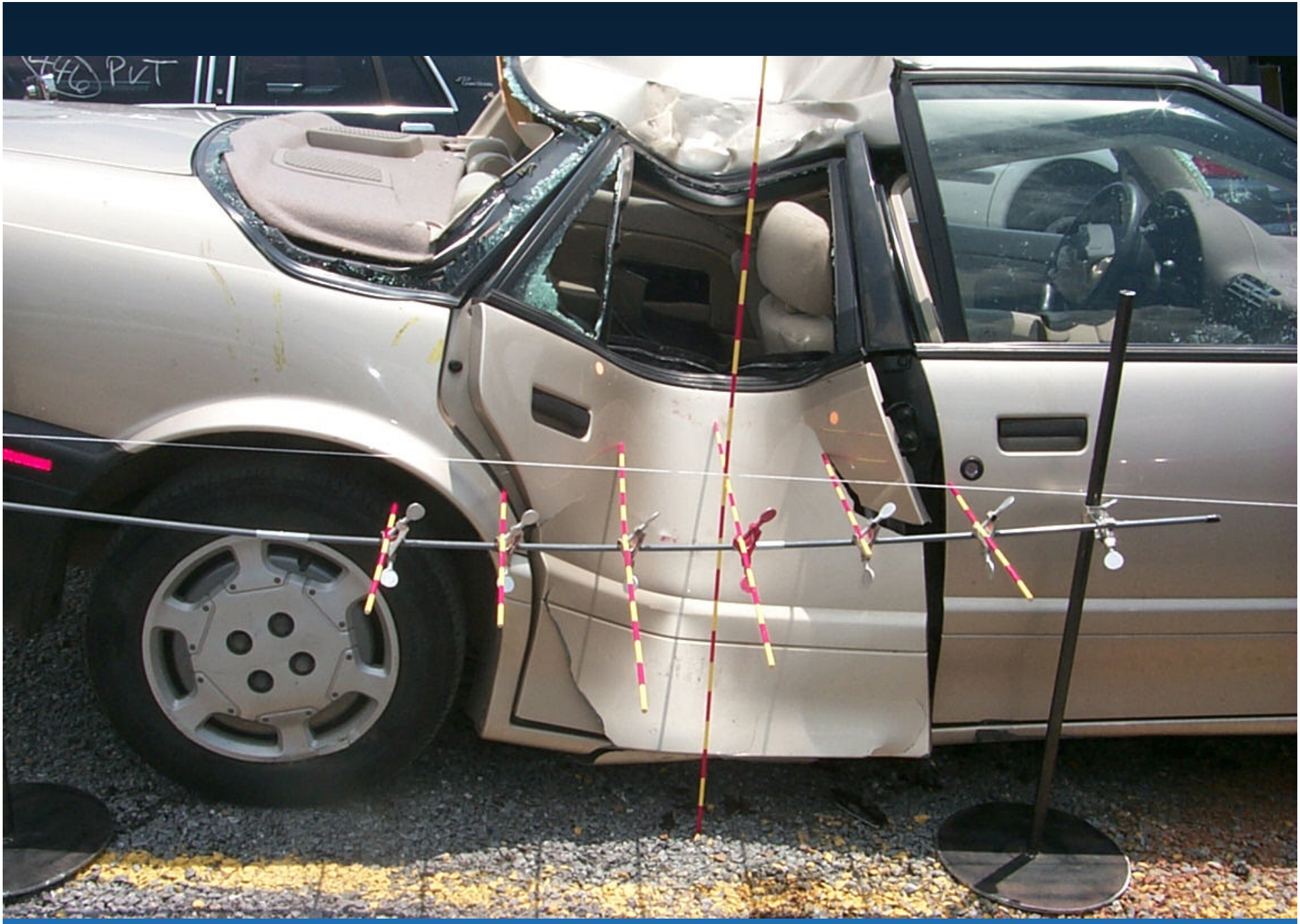
OCCUPANT CONTACTS

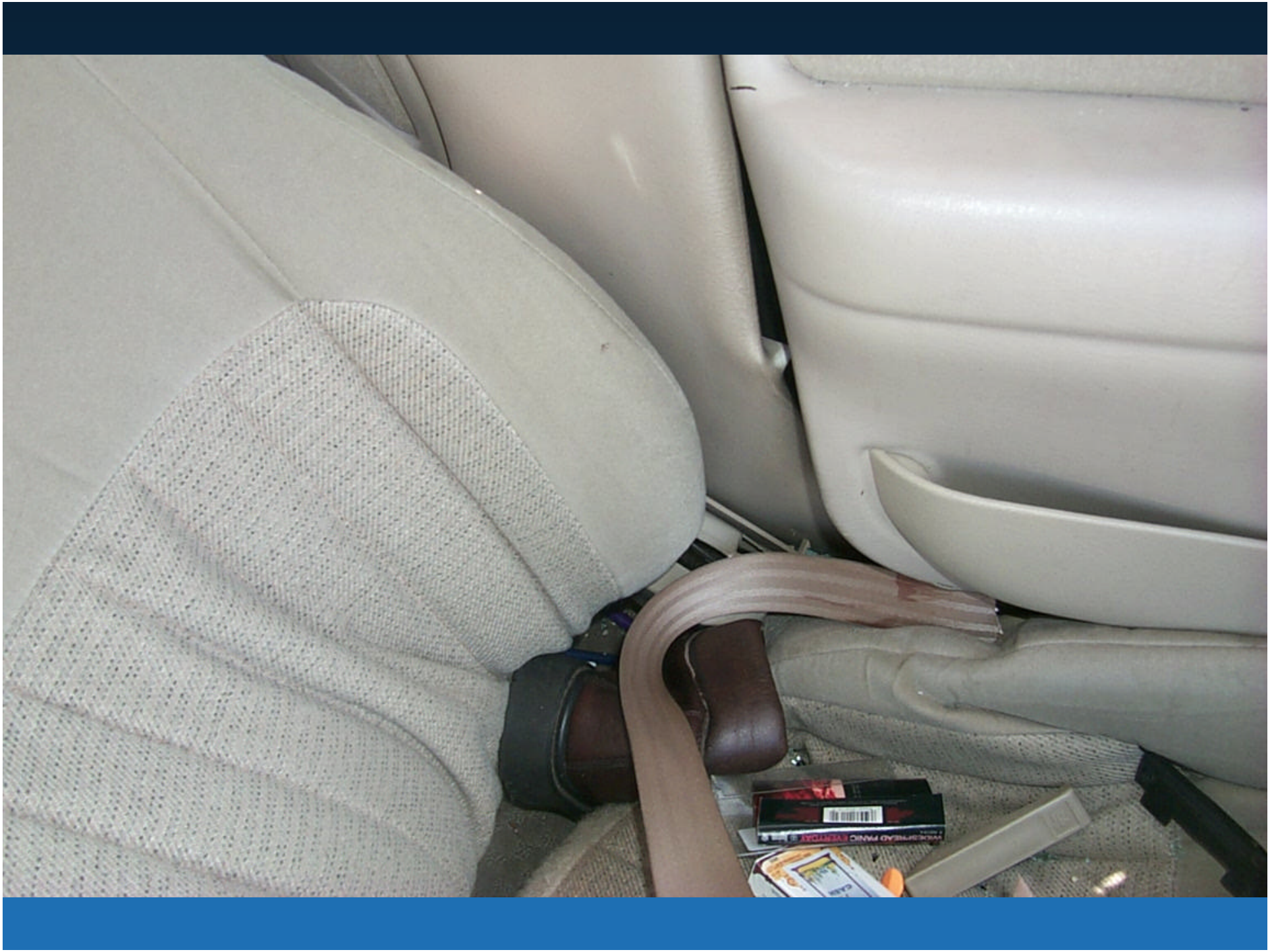
- LEFT DOOR PANEL — Intrusion / Blood
- LF SEATBACK — Smudged / Hair
- RF SEATBACK — Hair
- RIGHT ‘B’ PILLAR — Scuffed
- RIGHT REAR ROOF — Hair / Blood


N
RED - 1995 Saturn SL1
BLUE - 1991 Ford Escort
REFERENCE POINT
P.O.I. with Utility Pole
P.O.I. #1
V1
V2


ONLY
ONLY

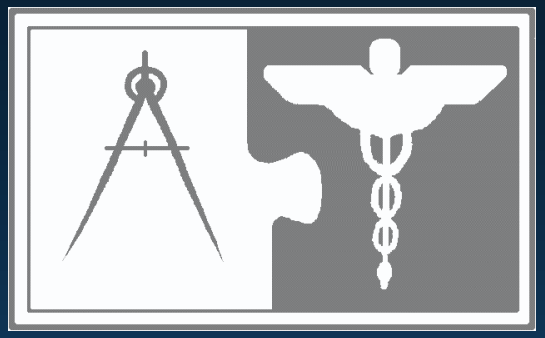
MAXIMUM CRUSH = 29 cm. / 11 in.





MAXIMUM INTRUSION = 20 cm. / 8 in.

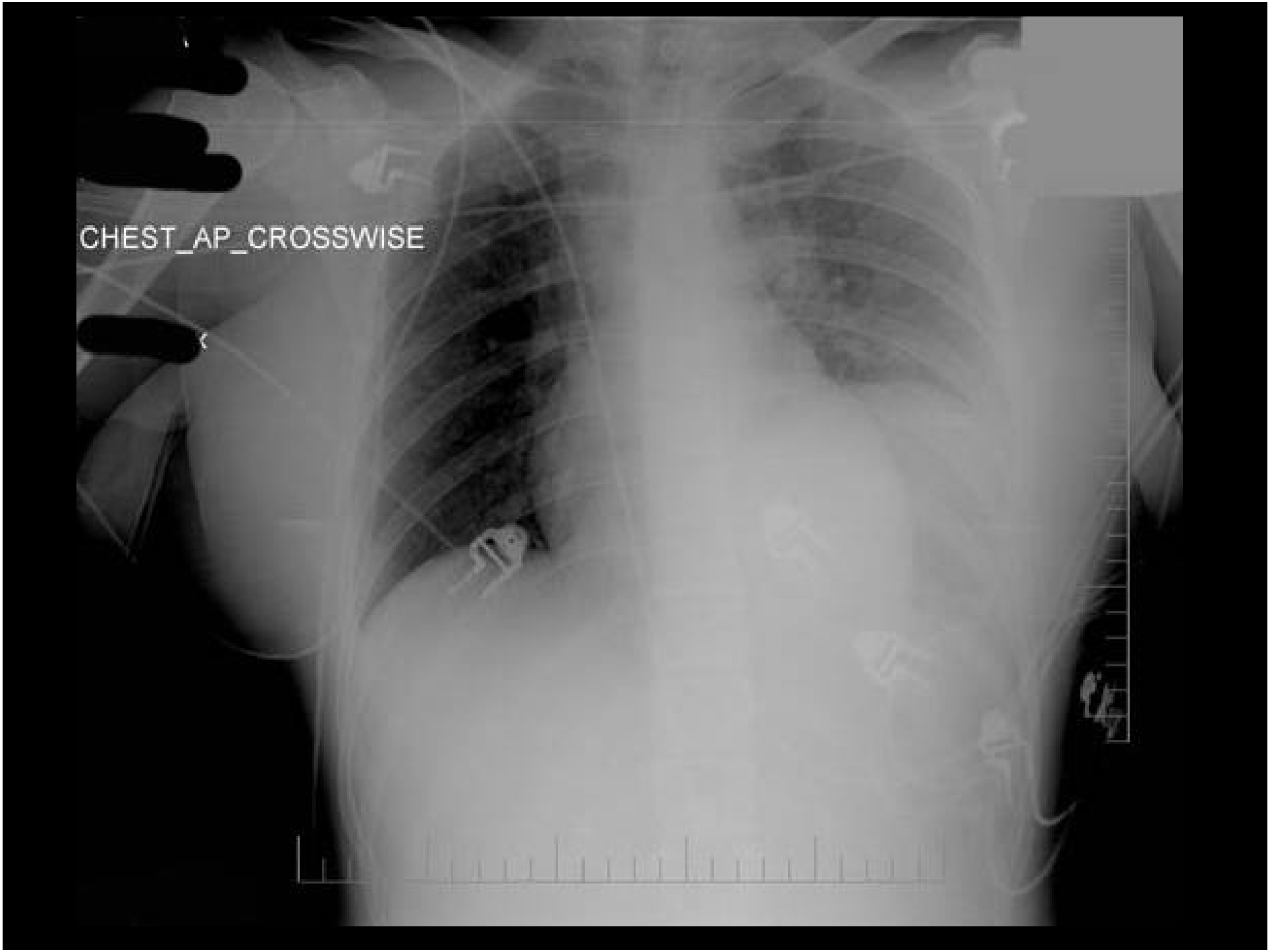

Original Bumper
Height = 32 cm. / 13 in.

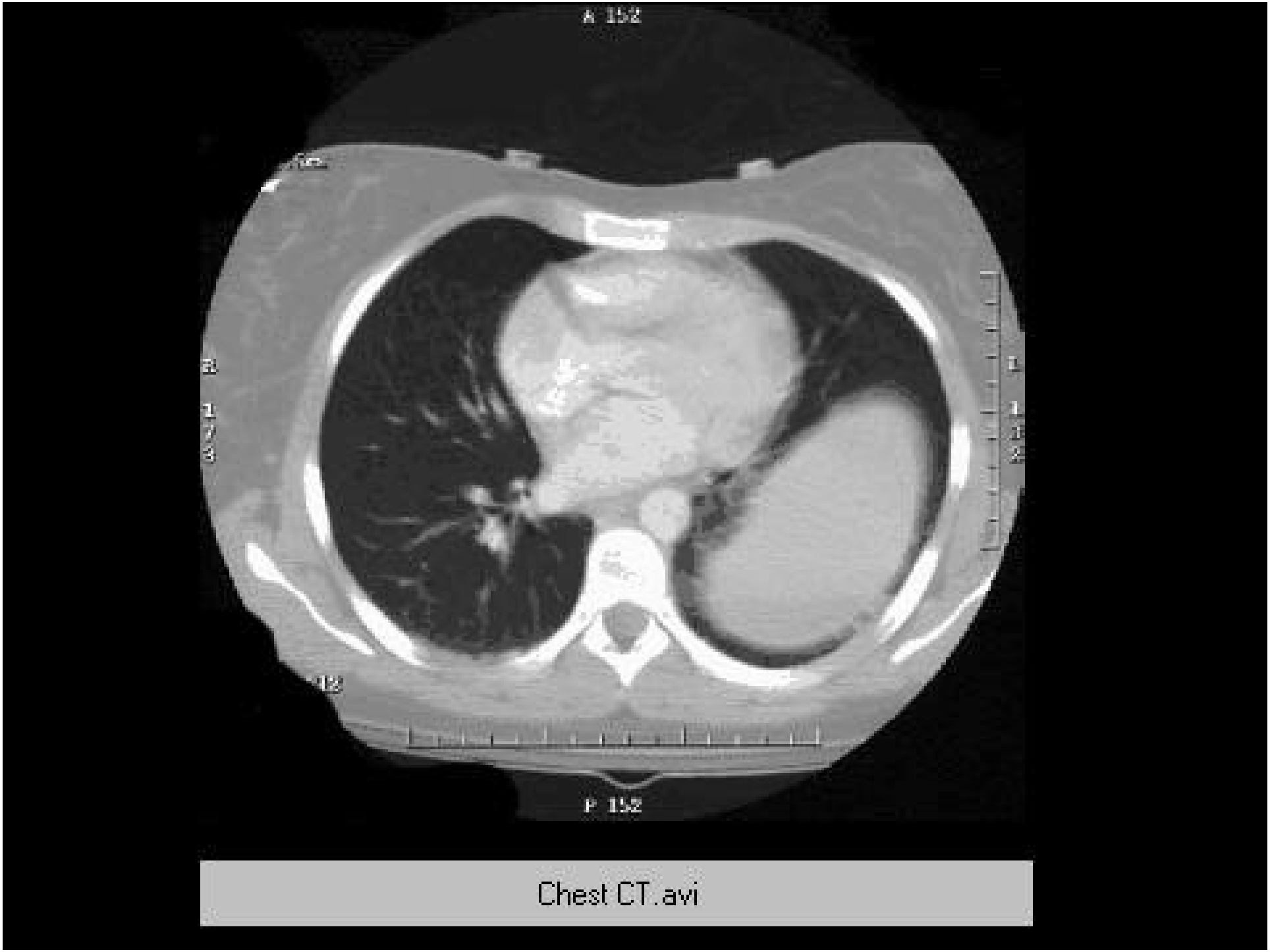


Injuries

- Grade IV splenic laceration
- Left diaphragmatic rupture
- Left superior/inferior pubic rami fracture
- Sacral fracture

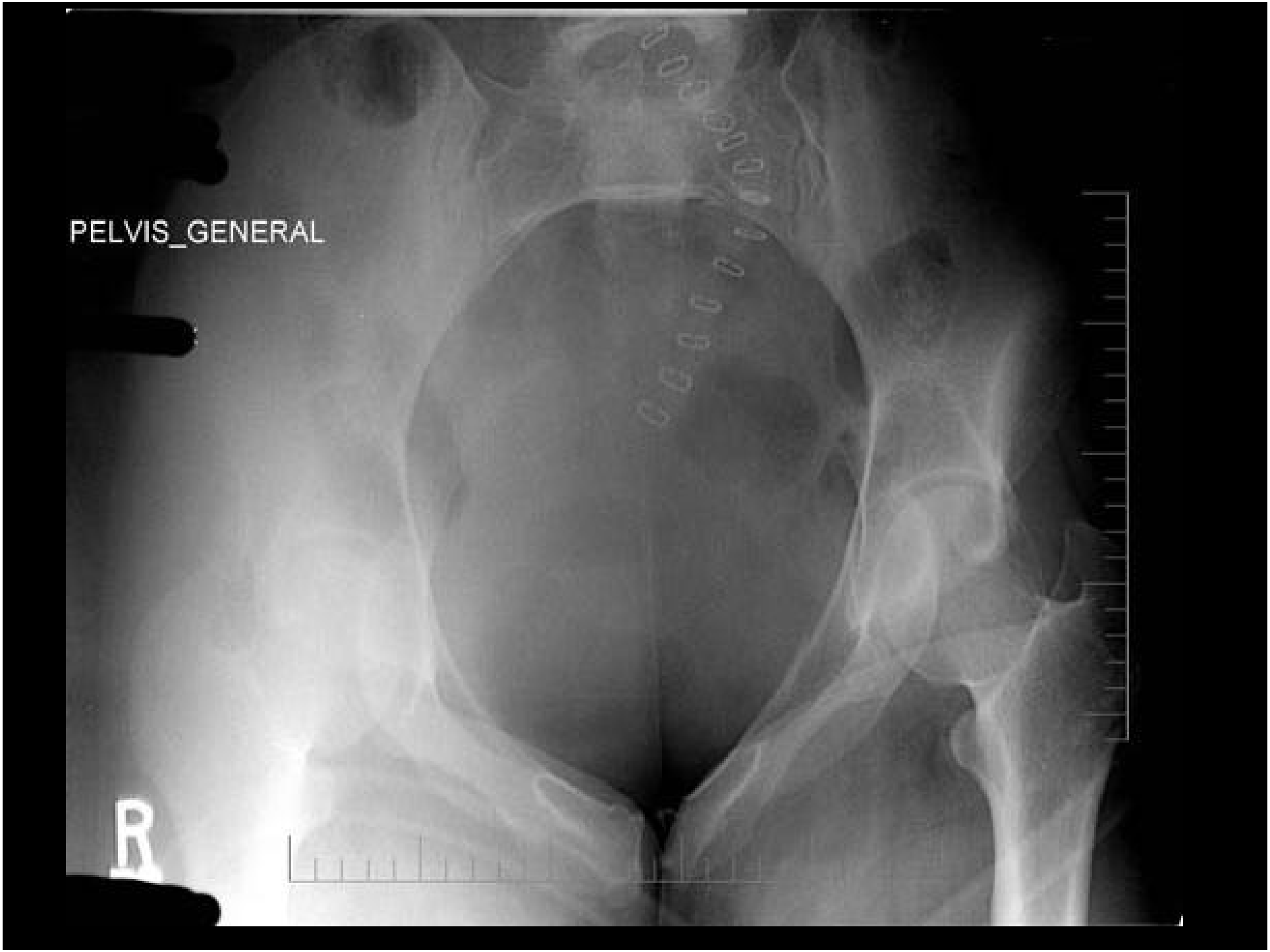
19 Spleen CT.avi

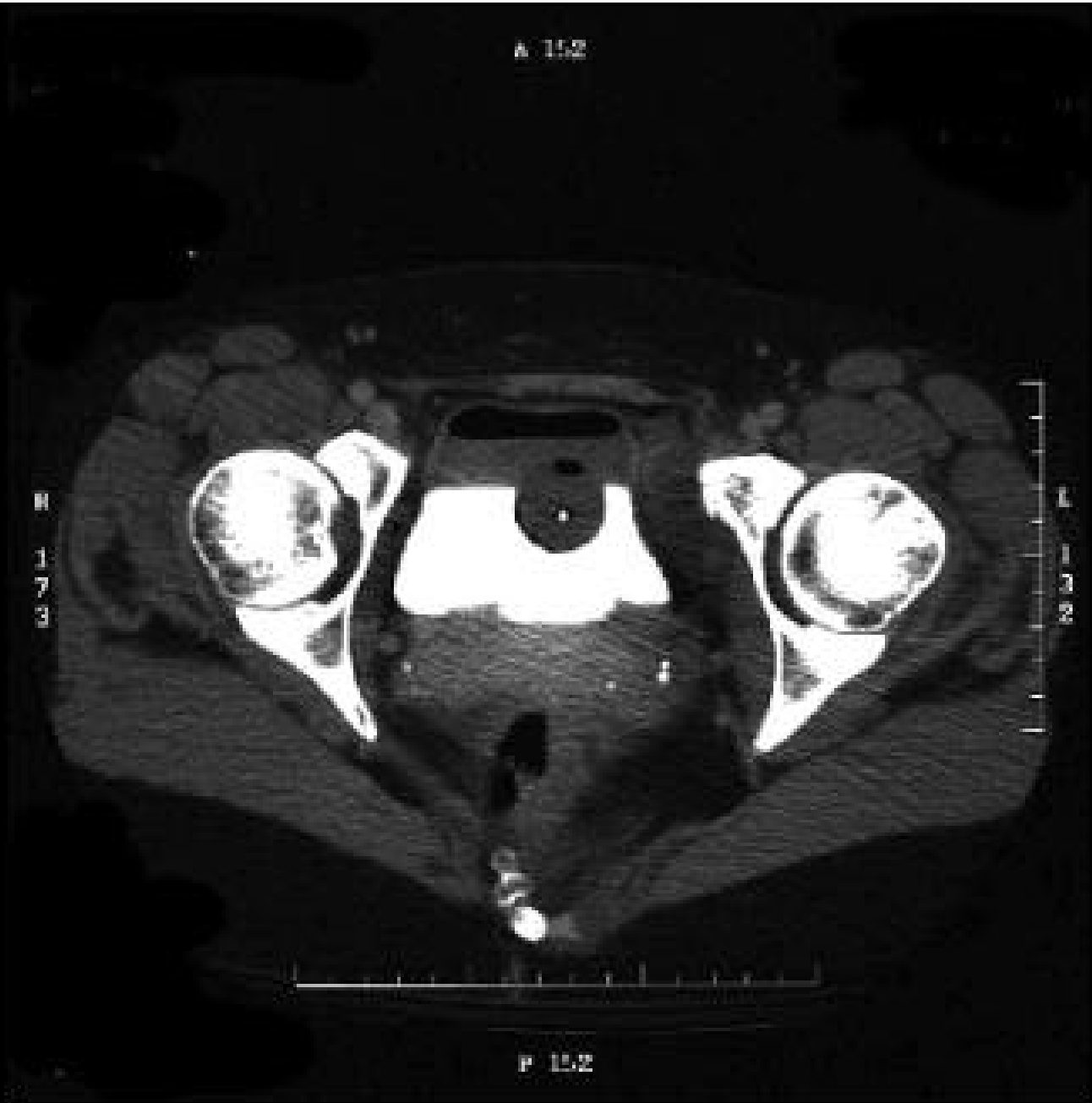

CHEST_AP_CROSSWISE



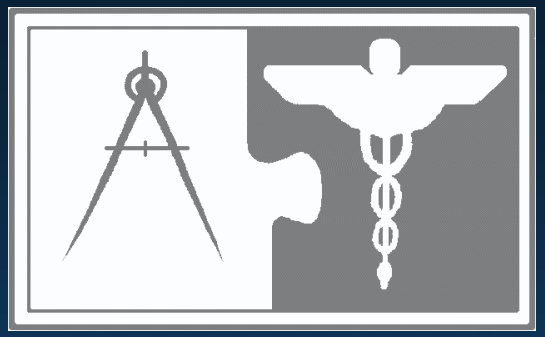
Chest CT.avi


PELVIS_GENERAL


PELVIS_GENERAL
R

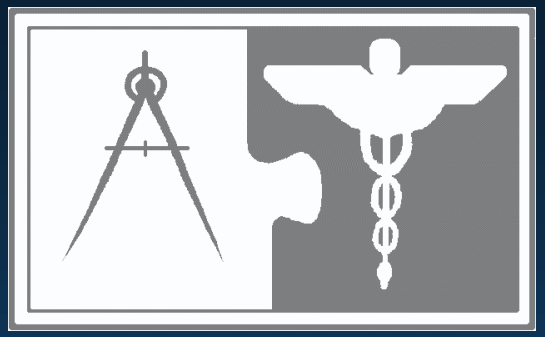


Pelvic CT 19.avi



Case Summary

- 50 year old restrained male driver of a 1994 Buick Skylark
- Required extrication from vehicle
- Reported to be confused en route



Case Summary

- PID#6 –ORIF of posterior column, posterior wall acetabular fracture
- Uncomplicated post operative course
- Discharged on PID # 11

CRASH DATA

- CASE VEHICLE 1994 Buick Skylark
- NON-CASE VEHICLE 1991 Ford Explorer
- TIME OF CRASH 5:20 p.m. / Daylight
- ROAD CONDITIONS Dry Asphalt / Clear
- TRAVEL SPEED 30 mph
- AVOIDANCE None
- RESTRAINTS Lap & Shoulder Belt

VEHICLE SPECIFICATIONS

1994 Buick Skylark

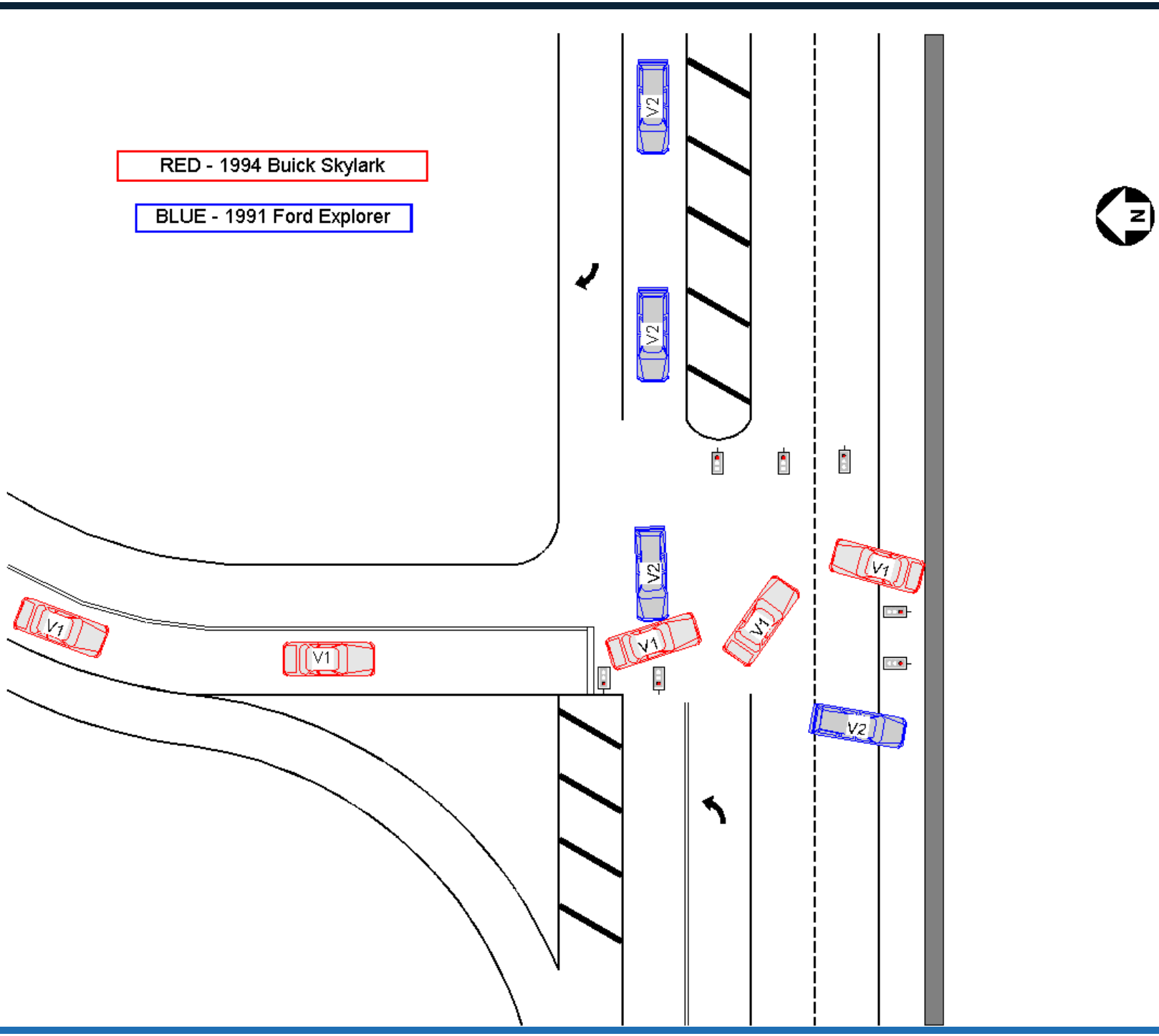
- WHEELBASE 263 cm. / 103 in.
- OVERALL LENGTH 480 cm. / 189 in.
- OVERALL WIDTH 171 cm. / 68 in.
- CURB WEIGHT 1300 kg. / 2865 lb.
- PDOF (Principal Direction of Force) -60 Degrees
- CDC (Collision Deformation Classification) 10LDAW3
- DELTA V 37 km / 23 mph

INTRUSIONS

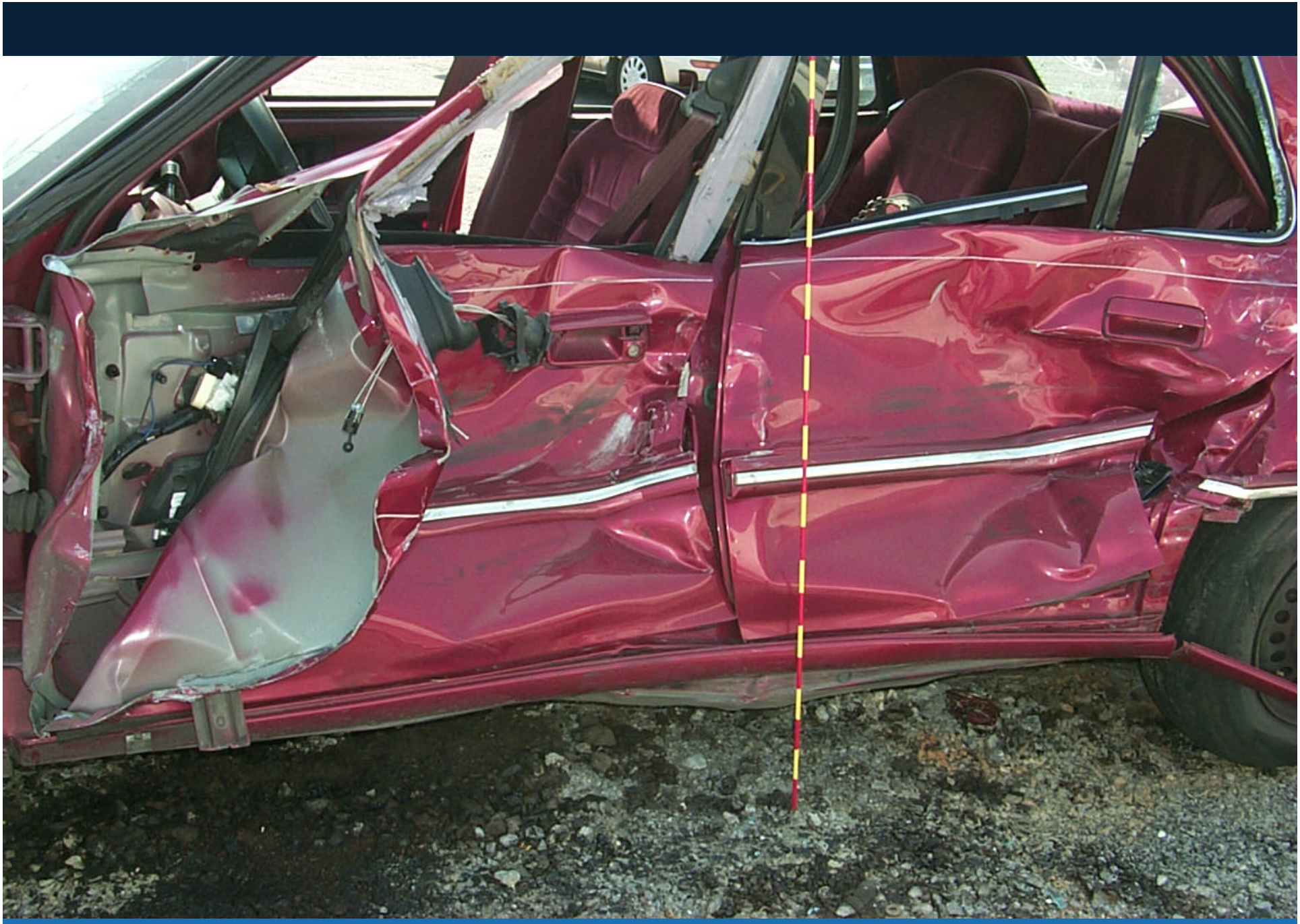
• LEFT DOOR PANEL	29 cm. / 9 in.	Lateral
• LEFT ‘B’ PILLAR	38 cm. / 15 in.	Lateral
• LEFT FRONT SILL	12 cm. / 5 in.	Lateral
• LF SEATBACK	22 cm. / 7 in.	Lateral
• LF ROOF SIDE RAIL	16 cm. / 6 in.	Lateral

OCCUPANT CONTACTS

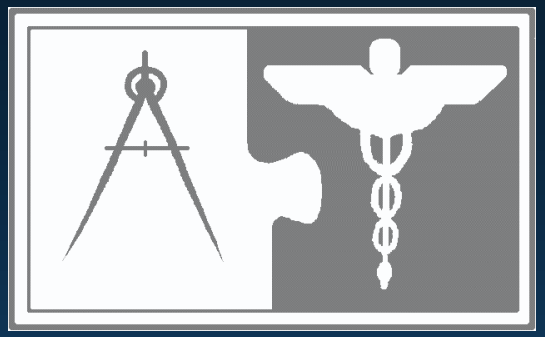
- LF DOOR PANEL — Blood
- LEFT ‘B’ PILLAR — Blood
- CENTER ARMREST — Pushed to Right


RED - 1994 Buick Skylark
BLUE - 1991 Ford Explorer
V1
V2
N


MAXIMUM CRUSH = 45cm. / 18 in.




MAXIMUM INTRUSION AT
DOOR PANEL = 20 cm. / 9 in.

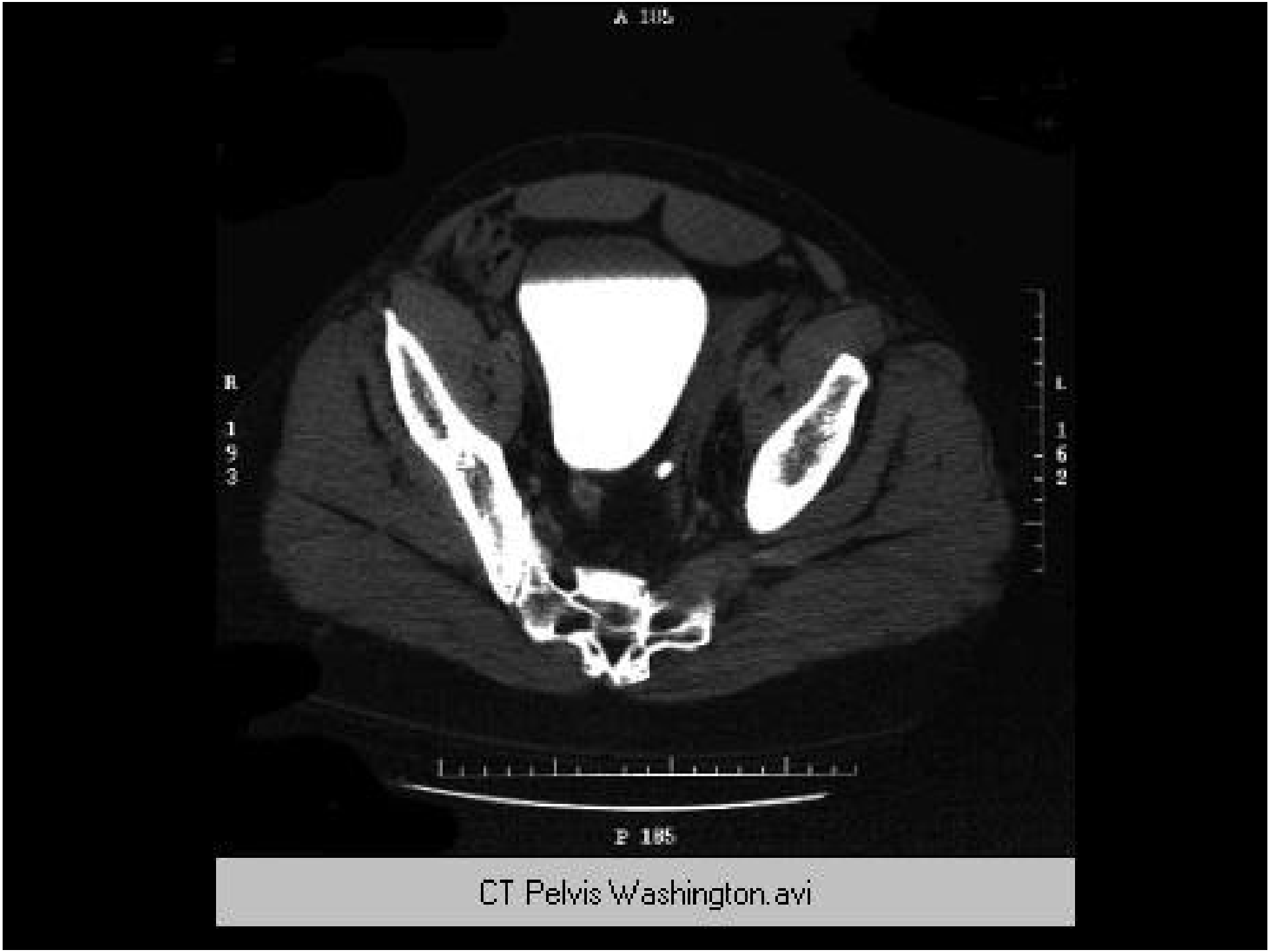


Injuries

- Left acetabular fracture
- Left 9th rib fracture
- Closed head injury with brief loss of consciousness


S03
M
IS: PELVIS_JUDET


R



CT Pelvis Washington.avi

Splenic Injury in Side Impact Motor Vehicle Collisions – The Role of Seatbelts

Donald A. Reiff, M.D., Gerald McGwin, Jr., M.S., Ph.D., and Loring W. Rue, III, M.D.

Center for Injury Sciences

University of Alabama at Birmingham

Background

- Seatbelts have been shown to reduce morbidity and mortality from motor vehicle collisions (MVCs).
- Seatbelt protects occupant from ejection and contact with vehicular components by restraining the occupant at the time of a crash.
- Does this restraint increase the risk of certain injuries resulting from intrusion into the occupant's seating position.

Hypothesis

Among drivers involved in near side impacts is there an association between seatbelt use and splenic injury?

Is this association dependent upon the magnitude of vehicle crush and stiffness?

Methods – Data Source

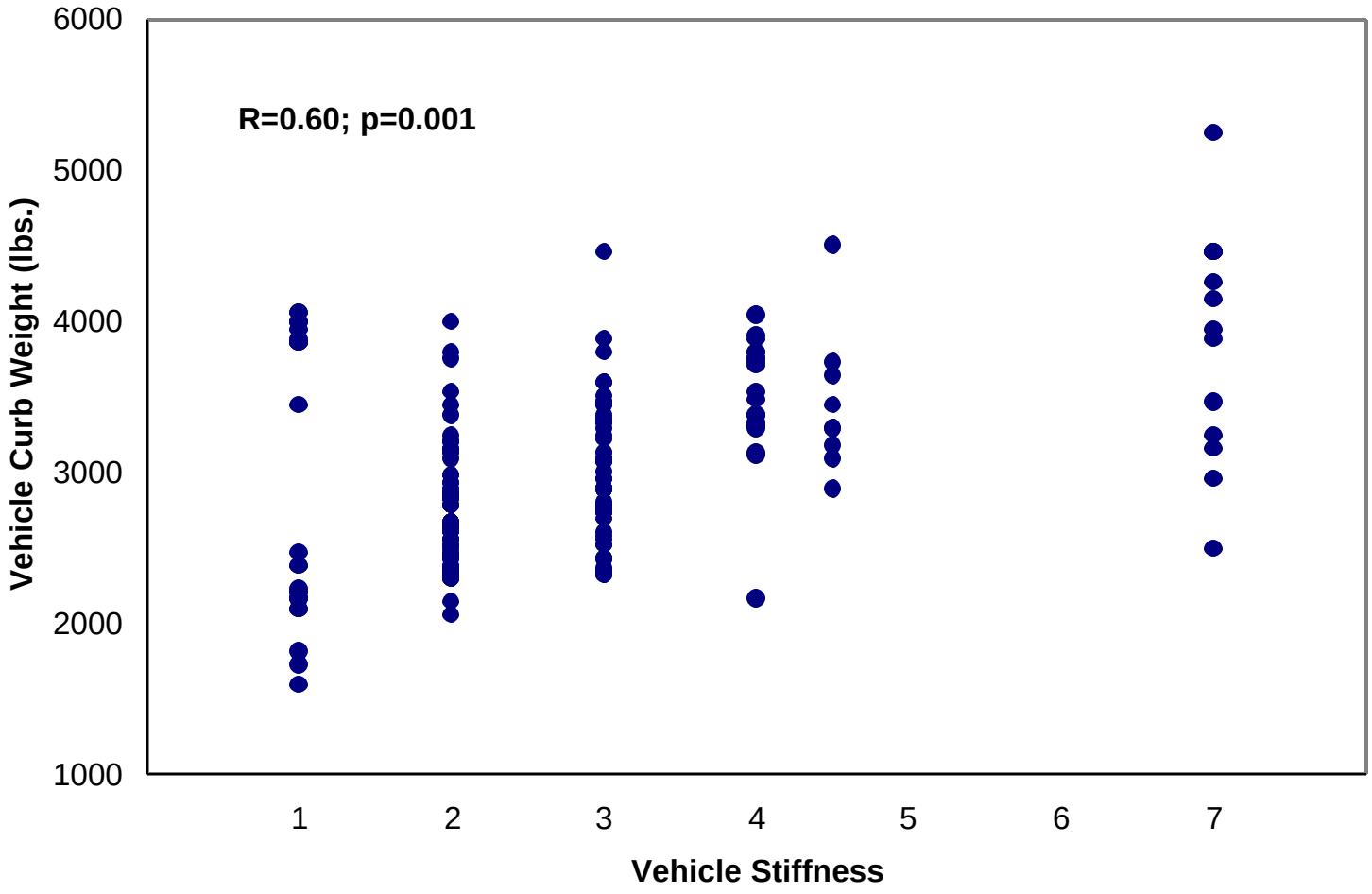
National Automotive Sampling System (NASS) data, 1996-1998

Methods - Definitions

- *Driver*
  - Primary role of occupant = driver (cross-checked with seating position in driver's seat)
- *Side impact*
  - Deformation location for highest ΔV = Left side
  - Specific location = side center section
- *Spleen injury*
  - AIS90 codes = 544210.2 through 544288.5
- *Seatbelt use*
  - Automatic or manual seatbelt use

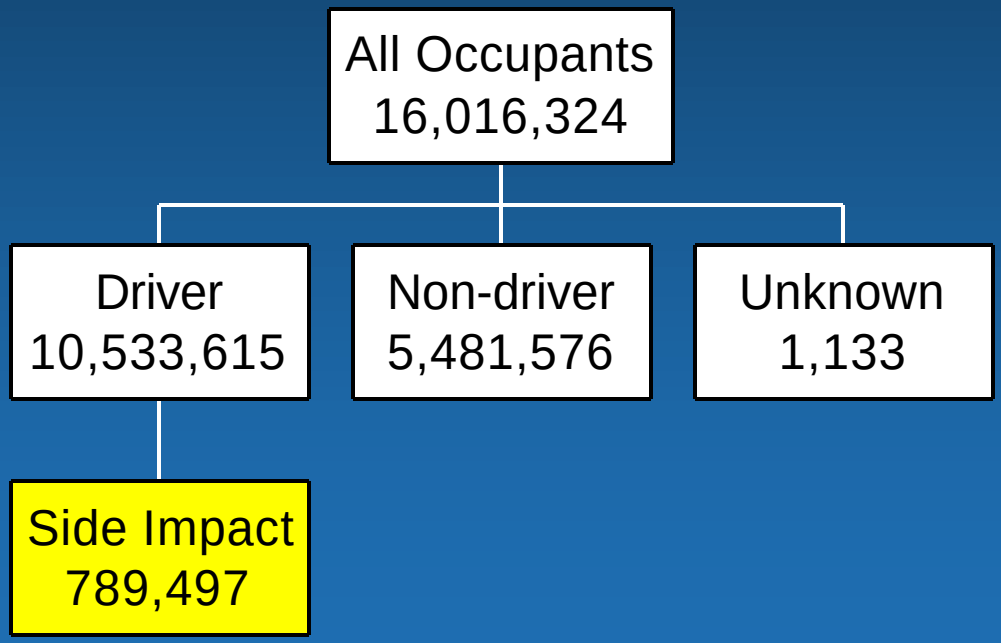
Methods - Definitions

- *Crush*
  - Maximum amount of crush associated with highest ΔV (left side of vehicle)
  - Two categories: 1-30 cm, 31+ cm
- *Vehicle stiffness*
  - Vehicle curb weight used a proxy for vehicle stiffness
  - Three categories: small (<2,500 lbs.), mid-size (2,500-3,000 lbs.), large (>3,000 lbs.)


R=0.60; p=0.001
Vehicle Curb Weight (lbs.)
6000
5000
4000
3000
2000
1000
1
2
3
4
5
6
7
Vehicle Stiffness

Methods – Study Population

NASS Data, 1996-1998
(Weighted)



	Number	Percent
Maximum crush (left side)		
0 - 30 cm	459,345	58.2
31- 152 cm	188,306	23.9
Unknown	141,846	18.0
Weight class		
Small (<2,500 lbs.)	184,655	23.4
Mid-size (2,500-3,000 lbs.)	235,482	29.8
Large (>3,000 lbs.)	364,949	46.2
Unknown	4,409	0.6
Seatbelt use (yes)	576,745	73.1

	Number Of Splenic Injuries	Rate*
Maximum crush (left side)		
0 - 30 cm	2,494	5.4
31- 152 cm	5,056	26.9
Unknown	956	6.7
Weight class		
Small (<2,500 lbs.)	2,109	11.4
Mid-size (2,500-3,000 lbs.)	2,980	12.7
Large (>3,000 lbs.)	3,417	9.4
Unknown	0	0.0
Seatbelt use		
No	3,399	16.0
Yes	5,107	8.9

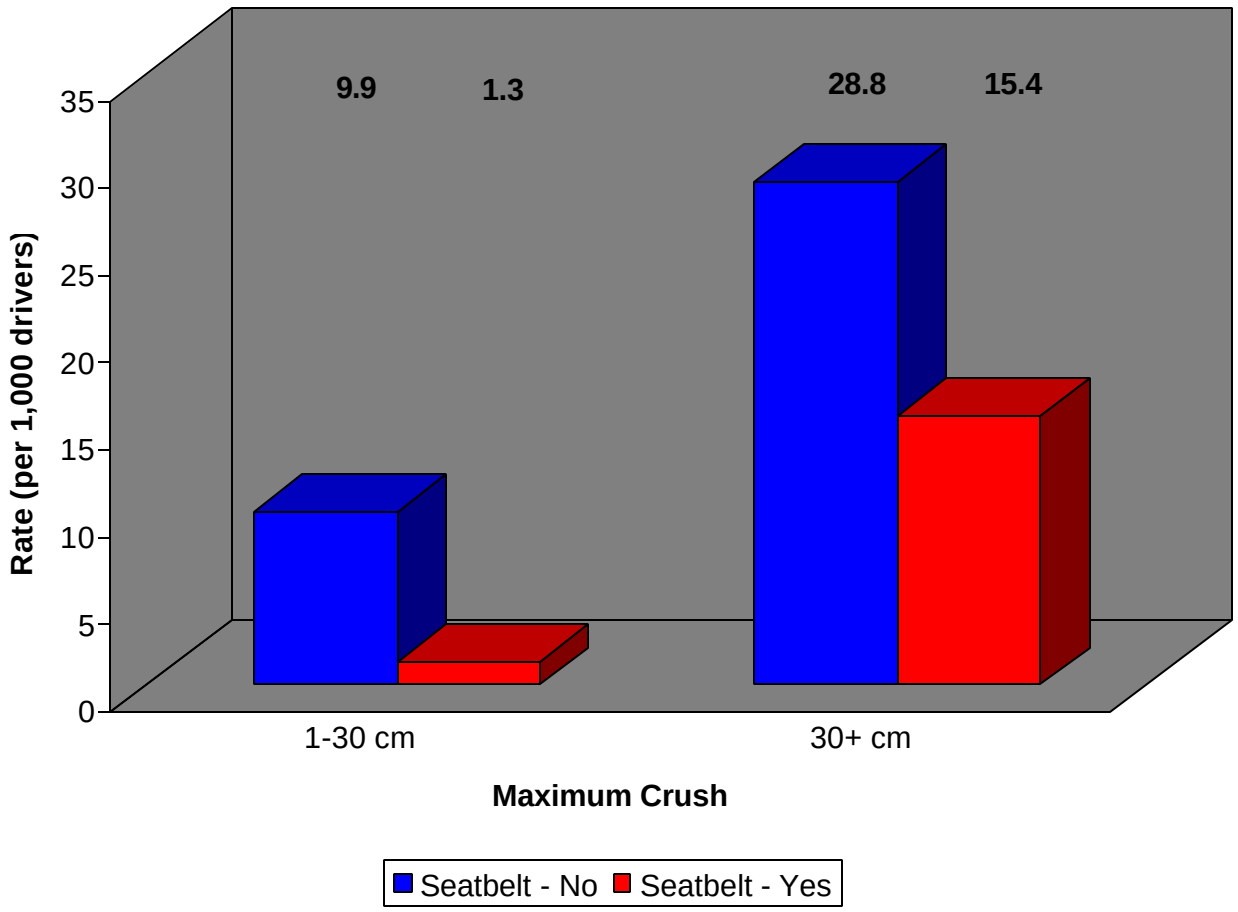
*Per 1,000 drivers (in side impacts)

Results

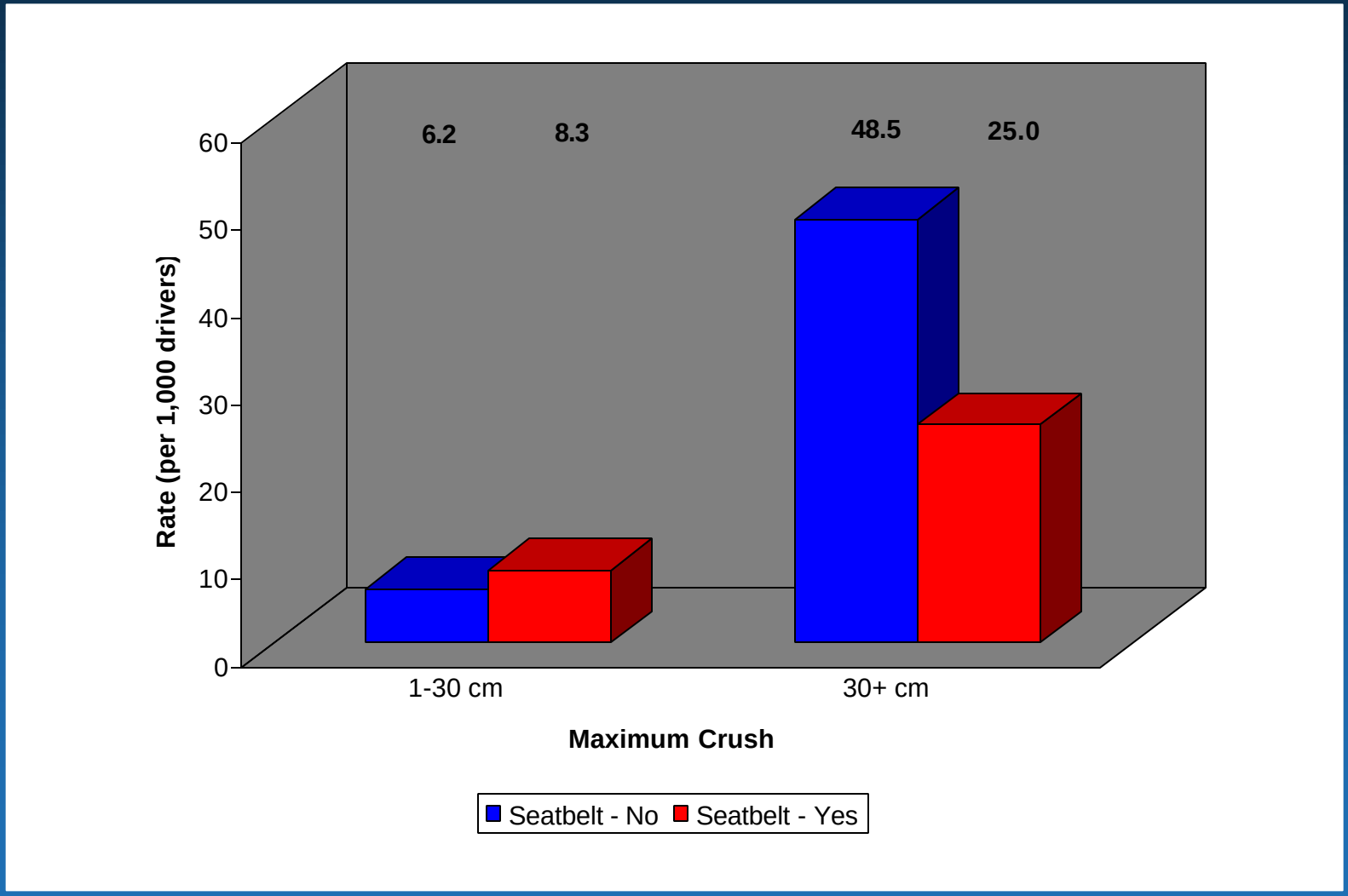
	Number	Rate*
Spleen injury	8,505	10.77
AIS-2	5,828	7.38
AIS-3	1,298	1.64
AIS-4	926	1.17
AIS-5	453	0.57

*Per 1,000 drivers (in side impacts)

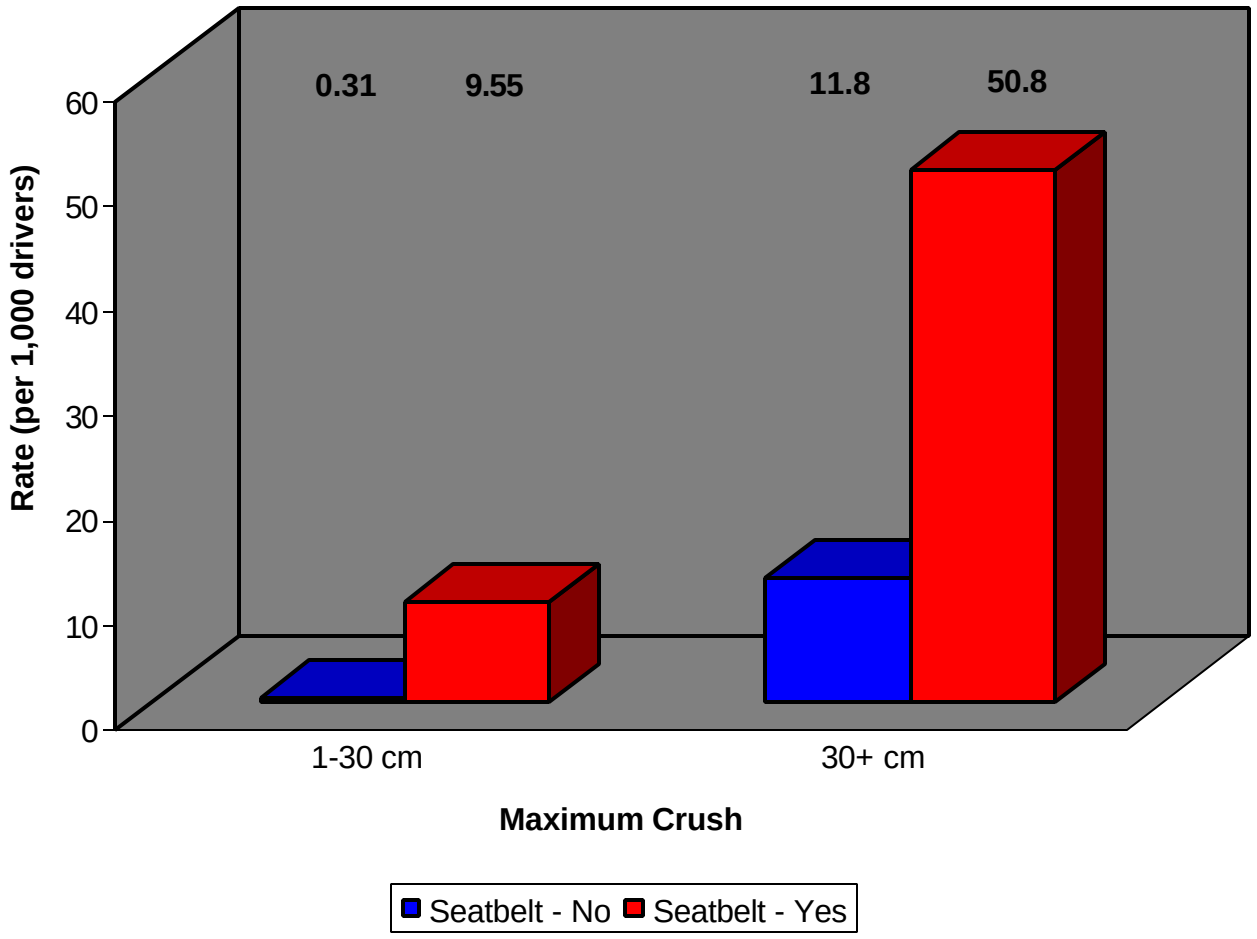
Results – Large Vehicles



Results – Mid-Size Vehicles



Results – Small Vehicles



Injury Source – Large Vehicles

	Crush 1-30 cm		Crush 30+ cm	
Seatbelt Use	No	Yes	No	Yes
Injury Source				
Left interior	18.3	64.8	98.7	93.8
Seatbelt	0.0	8.5	1.0	5.3
Other	81.7	26.7	0.4	0.9

Injury Source – Mid-Size Vehicles

	Crush 1-30 cm		Crush 30+ cm	
Seatbelt Use	No	Yes	No	Yes
Injury Source				
Left interior	100.0	92.1	97.3	100.0
Seatbelt	0.0	7.9	1.0	0.0
Other	0.0	0.0	1.7	0.0

Injury Source – Small Vehicles

	Crush 1-30 cm		Crush 30+ cm	
Seatbelt Use	No	Yes	No	Yes
Injury Source				
Left interior	100.0	100.0	100.0	87.5
Seatbelt	0.0	0.0	0.0	12.5
Other	0.0	0.0	0.0	0.0

Conclusions

- Overall, seatbelt use is associated with a lower risk of splenic injury in side impacts.
- Seatbelt use in large (stiff) vehicles afforded the greatest protection from injury in side impacts.
- Higher index of suspicion for splenic injury among belted drivers in side impact collision involving small vehicles.

Biomechanical Response of the Pelvis to Side Impact

- Surveillance
- Experimental
- FEM

Biomechanical Response of the Pelvis to Side Impact

- Surveillance
- Experimental
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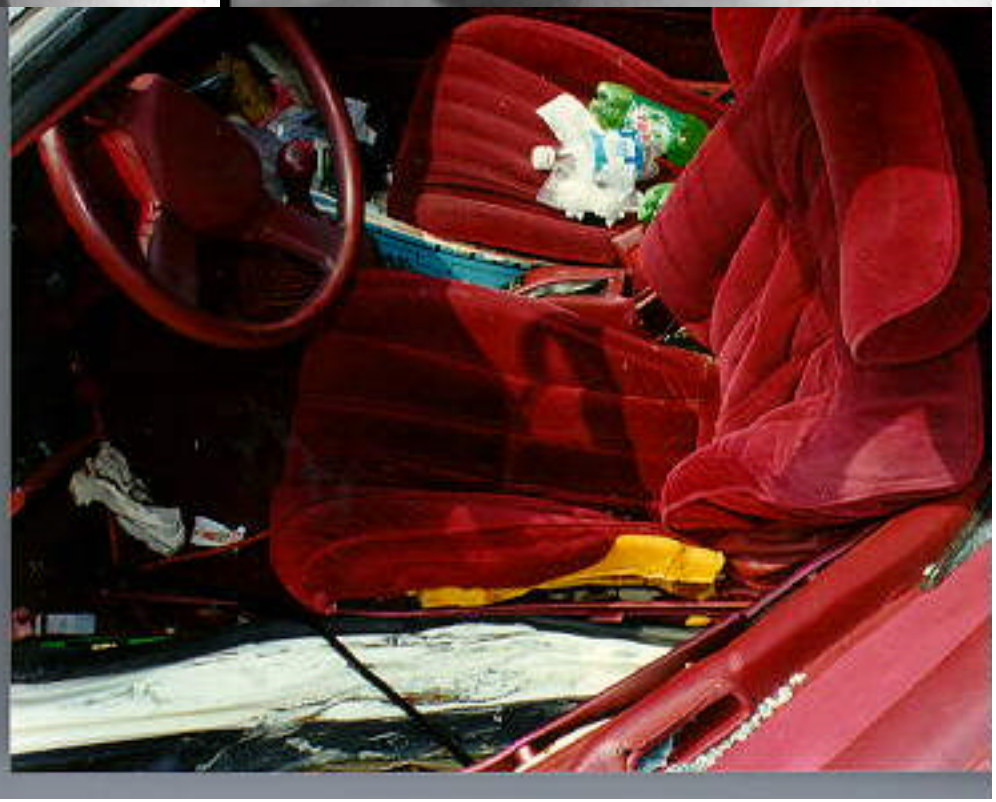
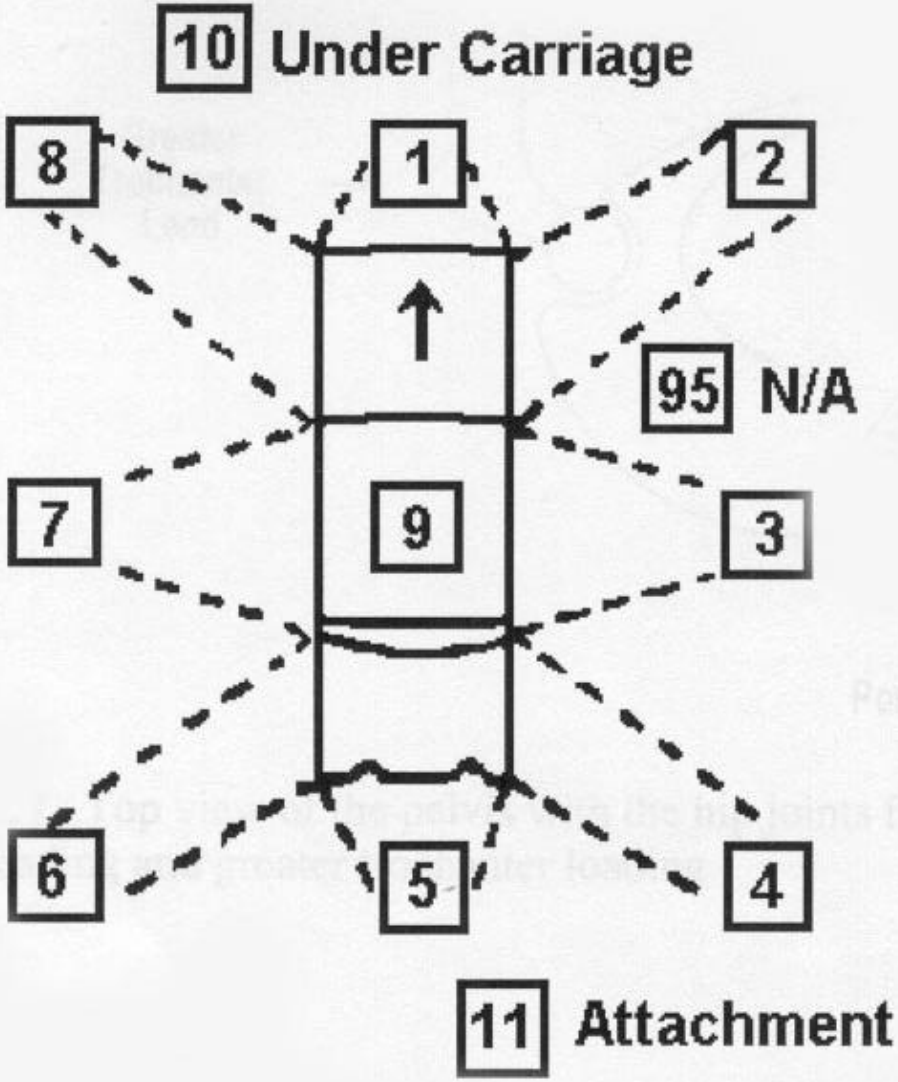
Acetabular Fracture Patterns: Associations with Motor Vehicle Crash Information

Greg J. Dakins, MS, Alan W. Eberhardt, PhD, Jorge E. Alonso, MD, James P. Stannard, MD, and Kenneth A. Mann, PhD

The Journal of Trauma: Injury, Infection, and Critical Care
Vol. 47, No. 6 ©1999



Circle areas Damaged on Diagram



Frontal Impact

FSA Loading

Fracture

68% of FSA type fractures occurred in frontal impacts ($p < 0.0008$)

Side Impact

GT Loading
Fracture

52% of GT type fractures occurred in side impacts ($p < 0.0001$)

Angled Frontal Impact

Off-axis Loading

Fracture

Most off-axis type fractures occurred in angled frontal impacts (p = 0.06)

83 Patients

41 Females **42** Males (32.4 Years)

Frontal - Males - Trucks

Off Axis - Females - 2 Doors.

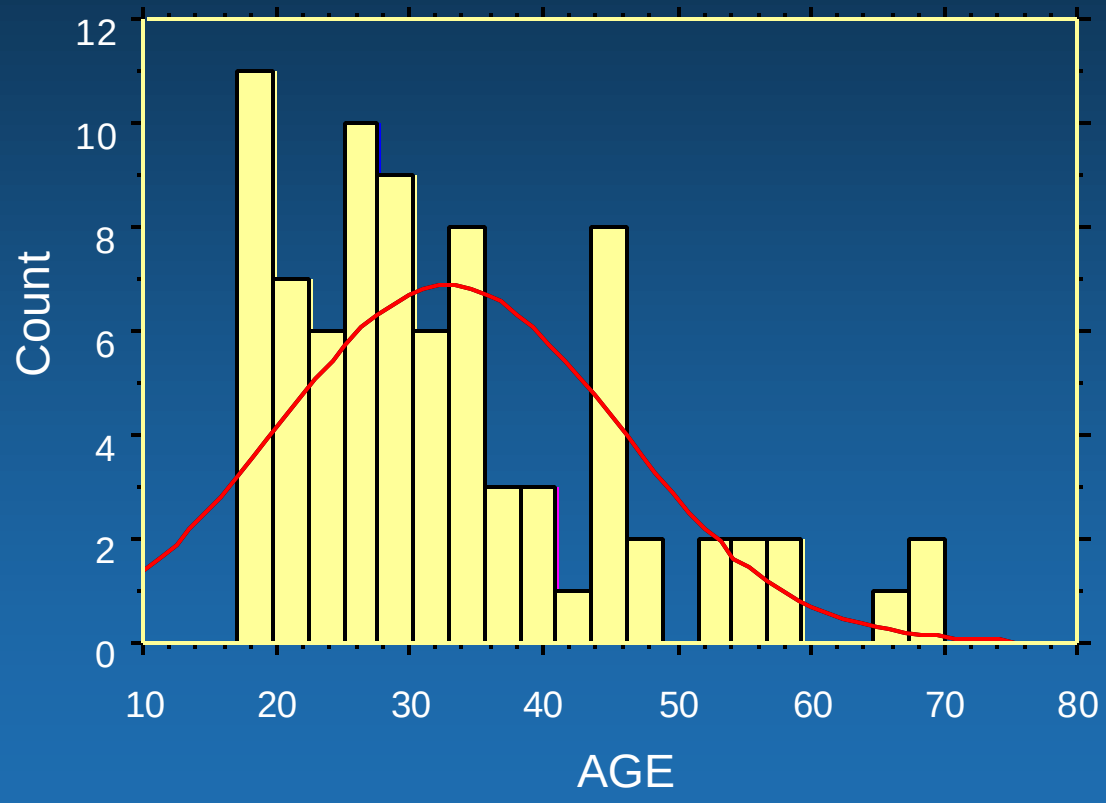
+ ***Common Transverse/Posterior Wall***

30 Fxs. 10 Belted/20 Not Belted

Frontal	**10**	2 Doors	**13**
Off Axis	**14**	4 Doors	**11**
Side	**2**	Trucks	**6**
Ejected	**4**		

Results: Age

- Range
  - 17 to 70
- Mean
  - 32.8 years old
- No significant correlation with fracture type



Results: Vehicle Type

2 Door cars

- 29 fractures
- Younger drivers
- 57% of side impacts*

4 Door cars

- 30 fractures
- Higher seatbelt usage*

Trucks

- 26 fractures
- No side impacts*
- 50% of the femoral shaft axis loading fractures*

Results: Gender

FEMALES

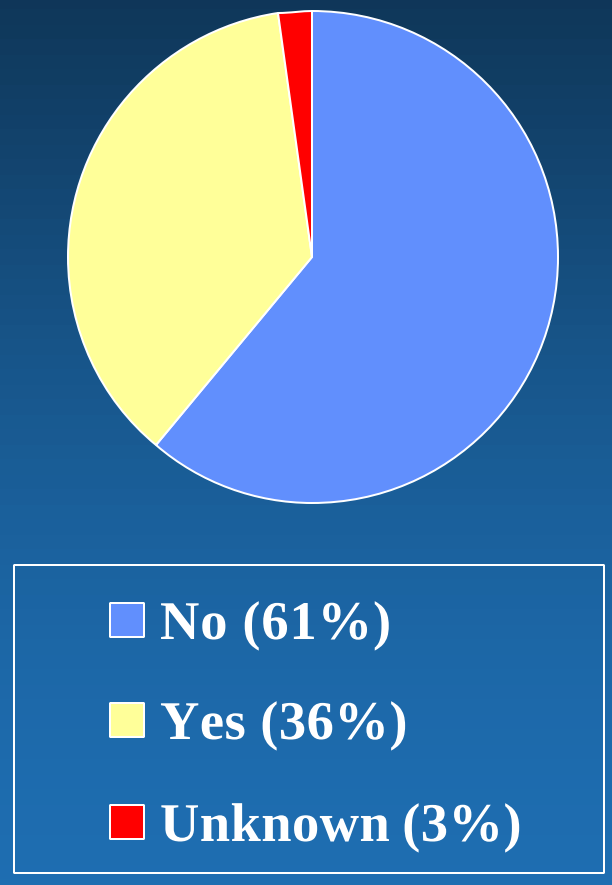
- 41 female subjects
- 46% injured in 2-door cars*
- 63% off-axis loading fractures*

MALES

- 42 male subjects
- 41% injured in trucks*
- 68% femoral shaft axis loading fractures*

* = ($p < 0.05$)

Results: Seat Belt Usage



- Seated position*
  - 56% unrestrained drivers
  - 93% unrestrained front seat passengers
- Unrestrained occupants more likely to be ejected
- No effect on fracture type

* = ($p < 0.05$)

Biomechanical Response of the Pelvis to Side Impact

- Surveillance
- Experimental
- FEM

Biomechanical Response of the Pelvis to Side Impact

Alan W. Eberhardt, Greg Dakin,

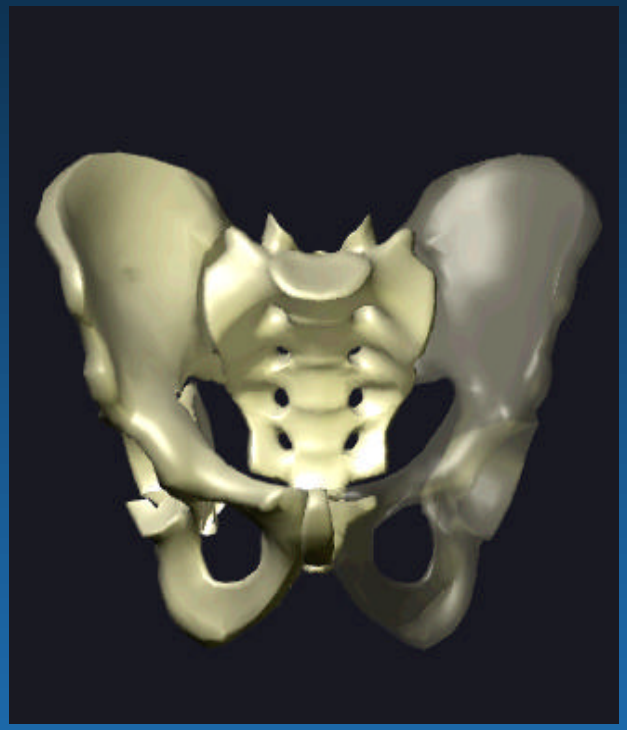
Ken Mann, Jorge Alonso*

Department of Biomedical Engineering, *Division of Surgery

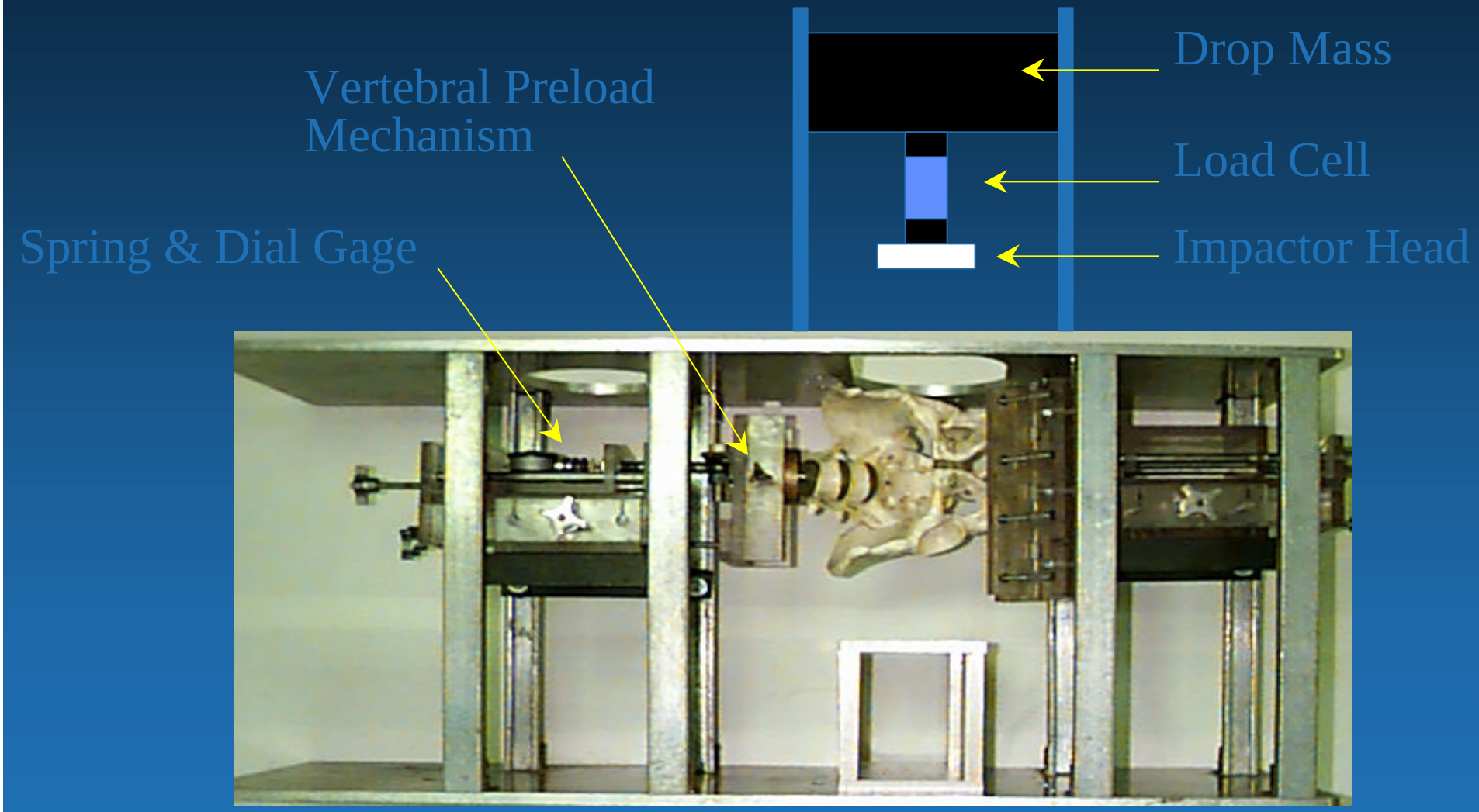
University of Alabama at Birmingham

Outline

- Surveillance
- Drop Tower Impacts of Isolated Pelves
- Finite Element Modeling
- Viscoelasticity of P-S and S-I Joints
- Future Directions



Drop Tower Impact Testing

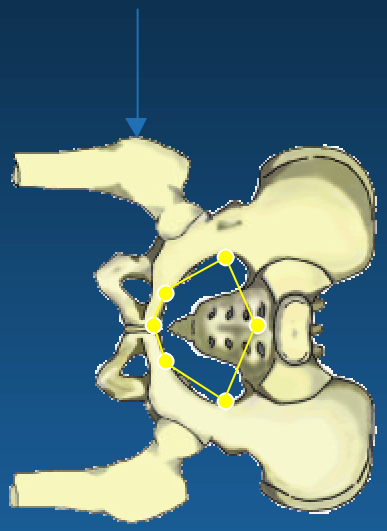


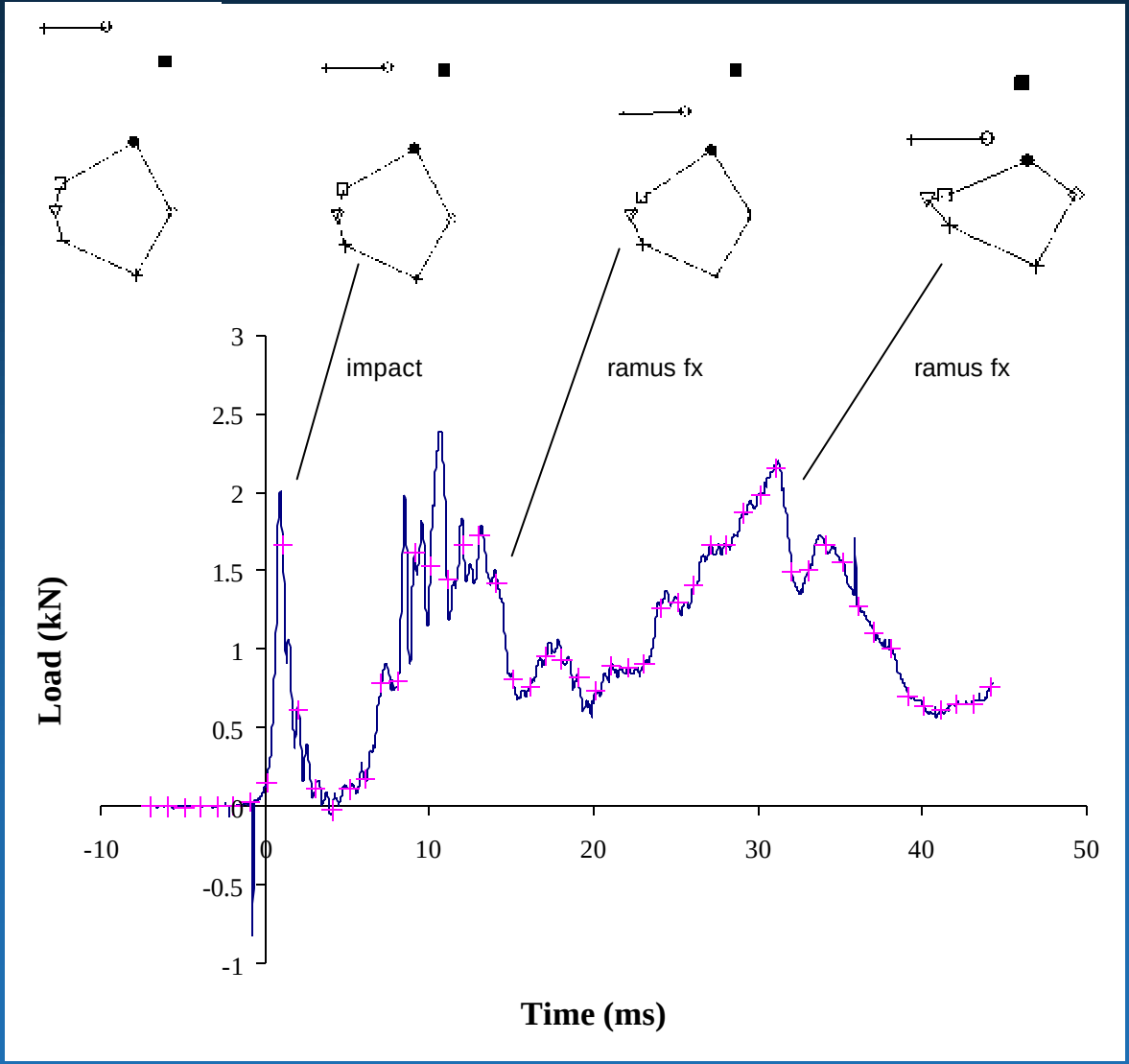
Specimen Preparation

- Fresh-frozen specimens
- Surrounding soft tissue removed and L4 vertebra potted in bone cement
- 7 mm IR reflective markers placed along the pelvic ring

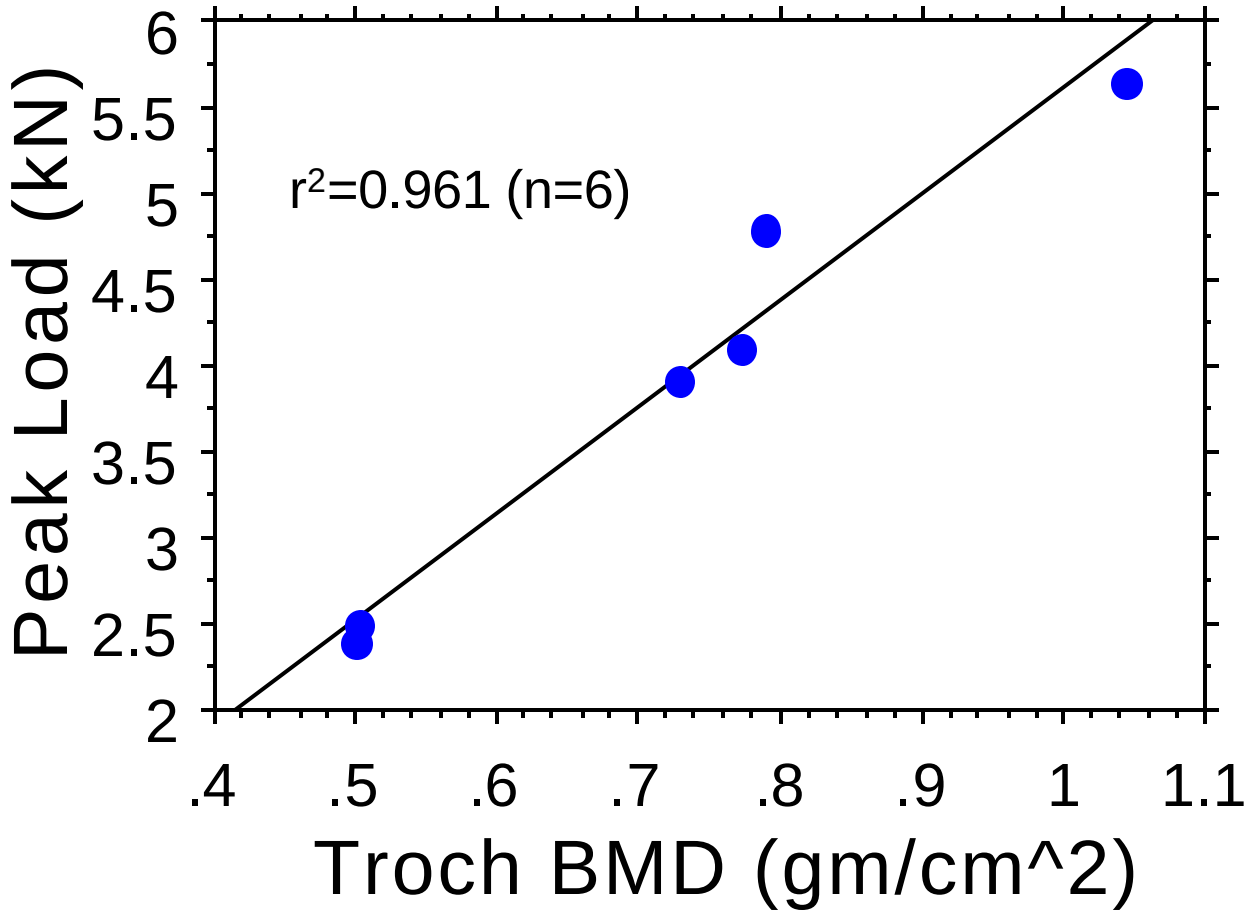
Results - Pelvis #63

Load greater trochanter



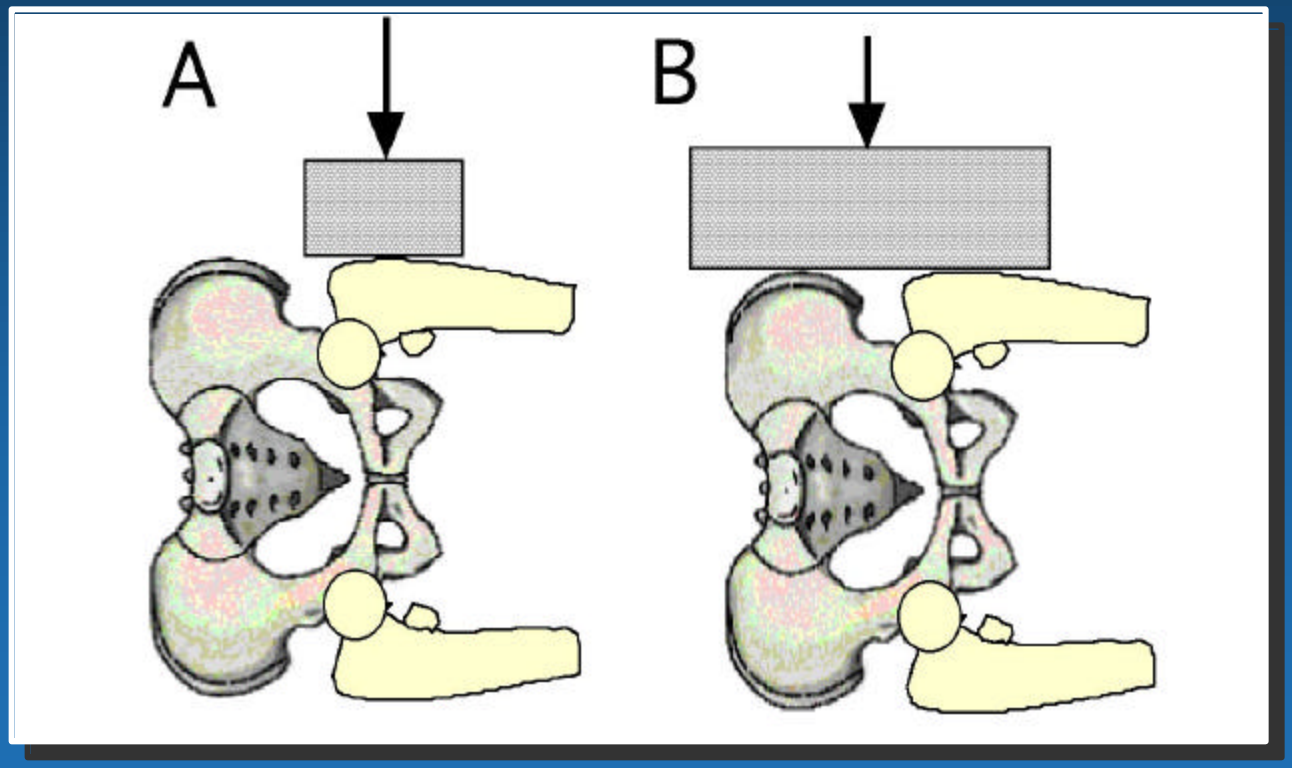


Results - Peak Load vs. BMD



Current Efforts

Effects of Load Path on
Fracture Tolerance & Patterns



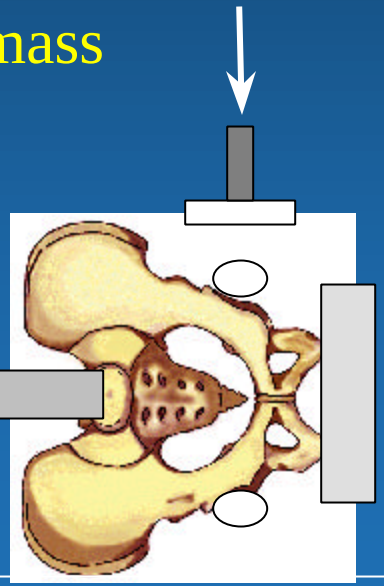
Previous Efforts

- Two Support Conditions
  - Drop mass varied to achieve F_{max} = 5 kN
  - Affected the Loading Rate
    - 10-20 msec pulse in cadaver impacts (Viano, 1989)

Iliac Wing Support

25 kg drop mass

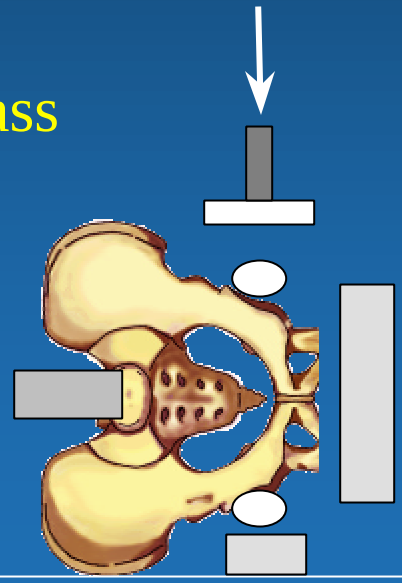
65% Preload



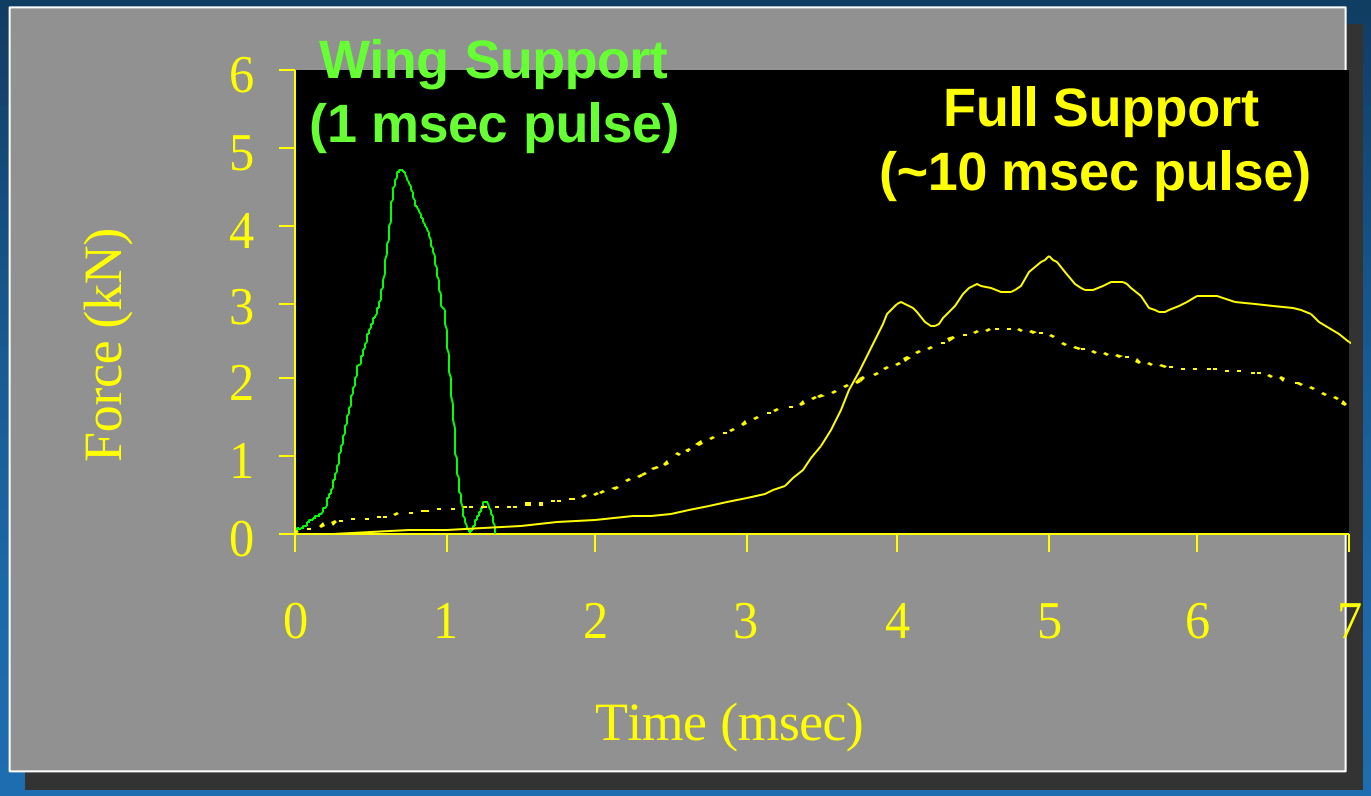
Full Support Condition

13 kg drop mass

65% Preload



$$\text{Loading rate} = \frac{\text{Peak Force}}{\text{Time to Peak Force}}$$



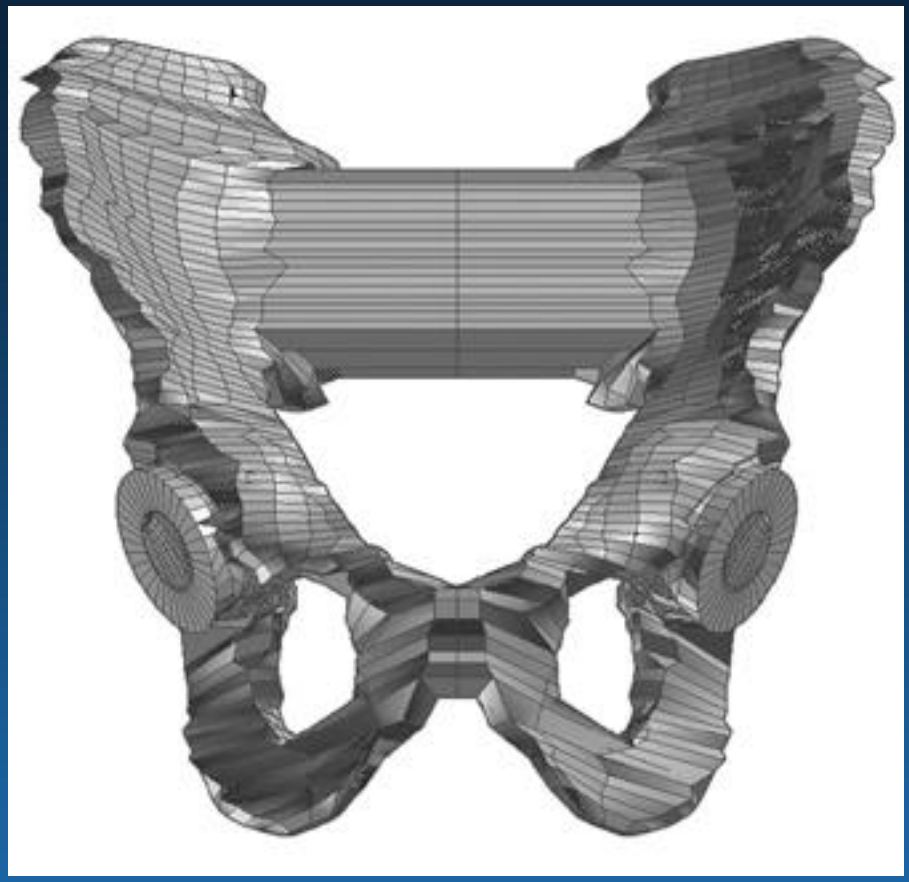
Previous Results: Injuries

Injuries	Wing Support: High Load Rate	Full Support: Low Load Rate
Rami Fracture	0	5
Acetabular Fracture	4	0
No Injury	4	1

Biomechanical Response of the Pelvis to Side Impact

- Surveillance
- Experimental
- FEM

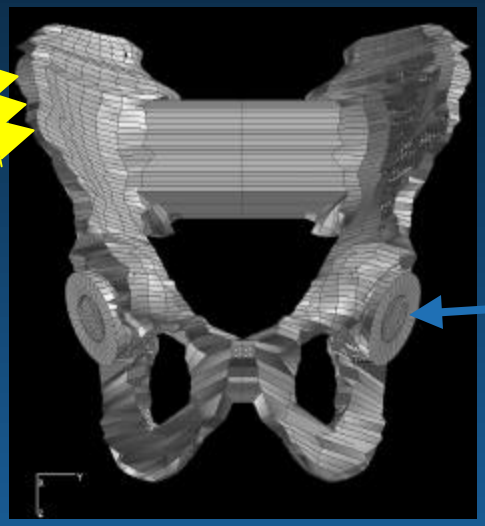
Dynamic Finite Element Simulations



Why experimental support conditions & loading rates result in different fracture types??

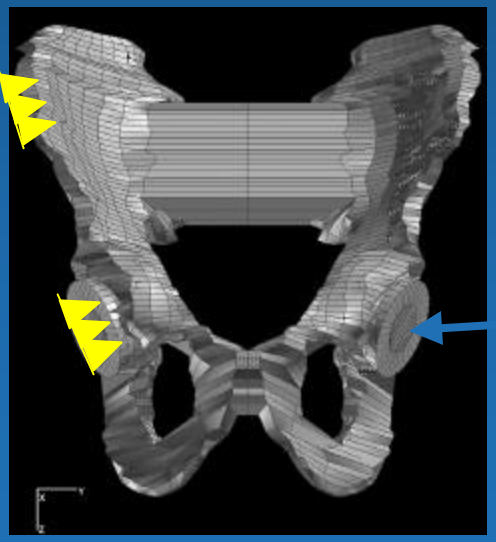
Supports & Loading Rates

Wing Support



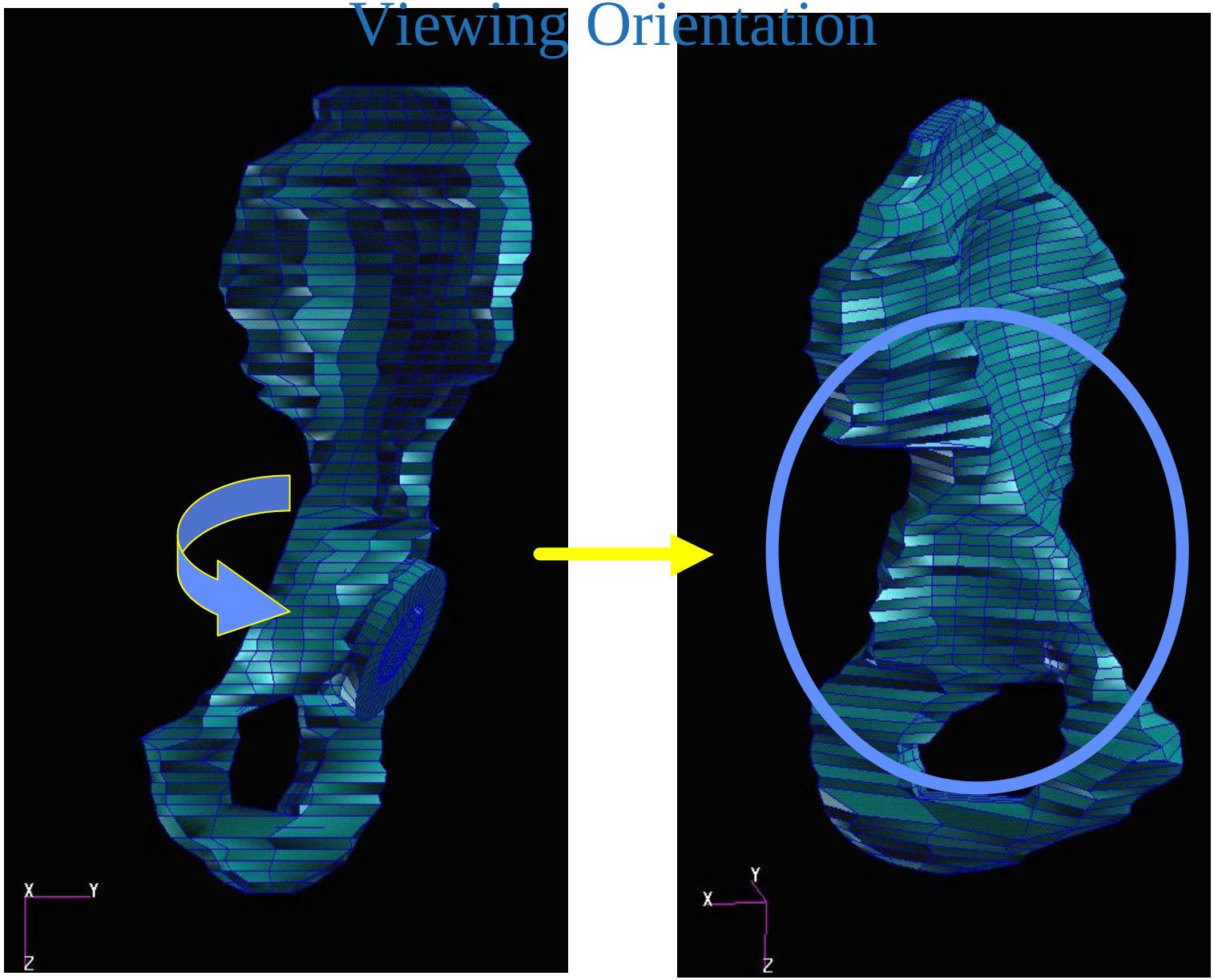
5 kN Impact force applied over 1 msec triangular pulse

Full Support



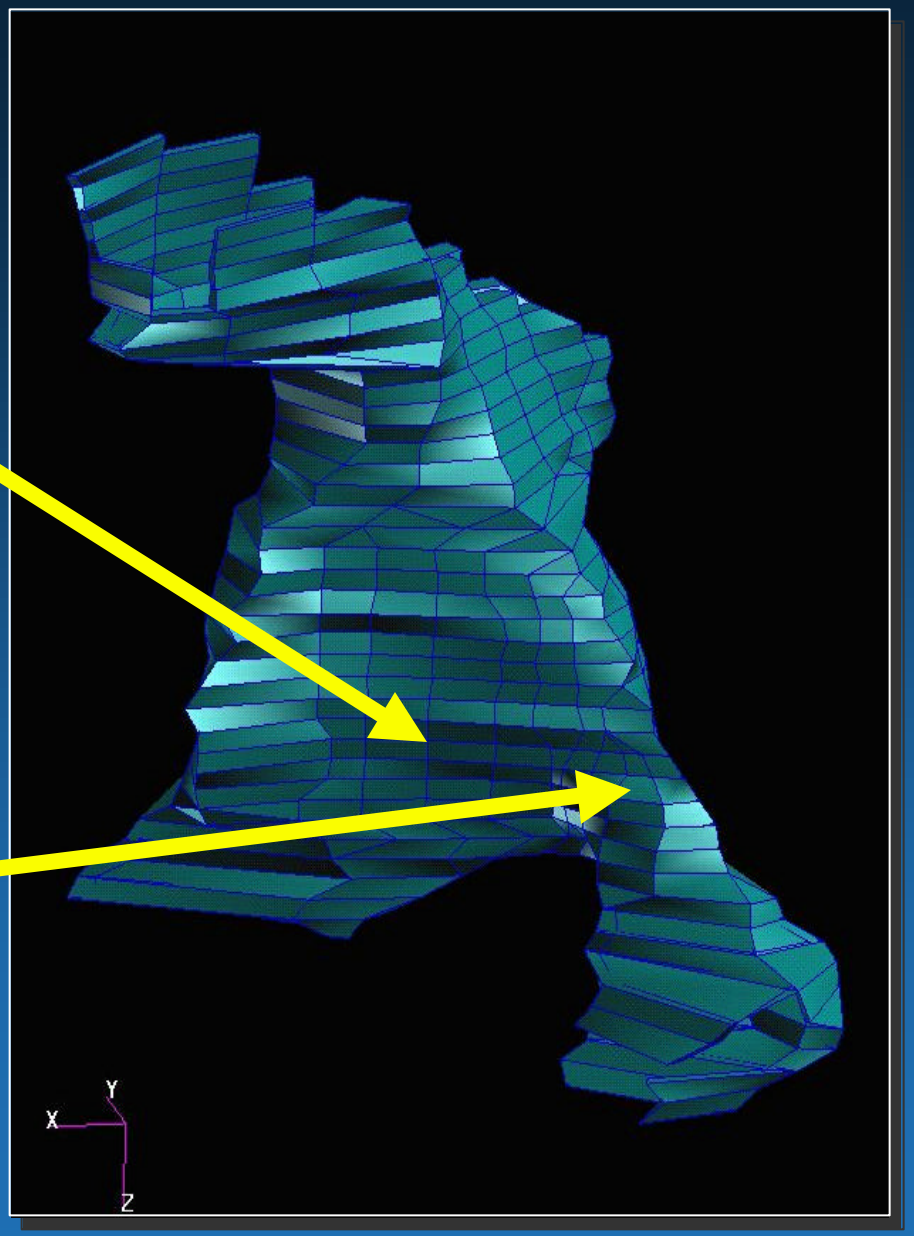
5 kN Impact force applied over 20 msec triangular pulse

Viewing Orientation

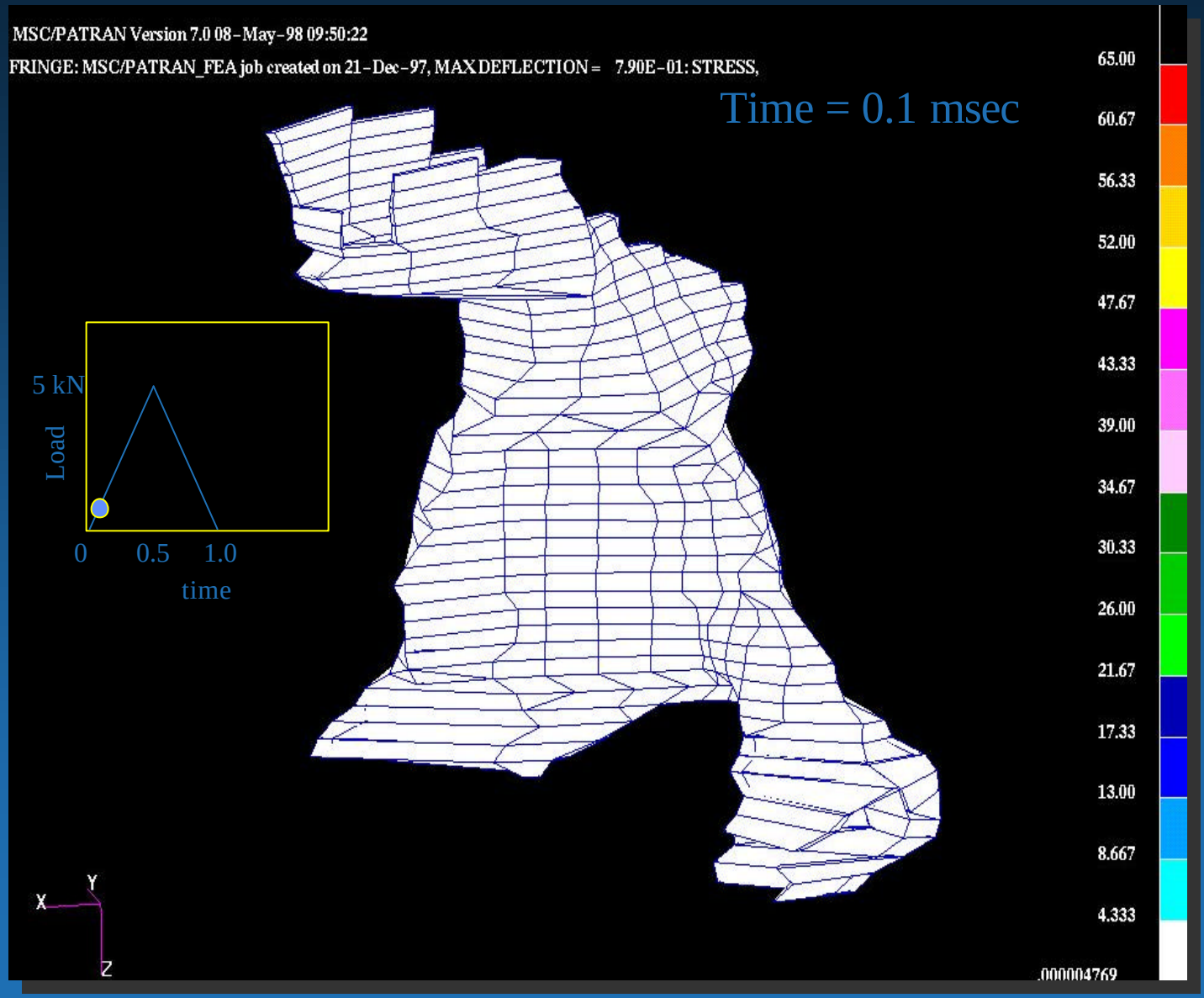


Region behind the acetabulum

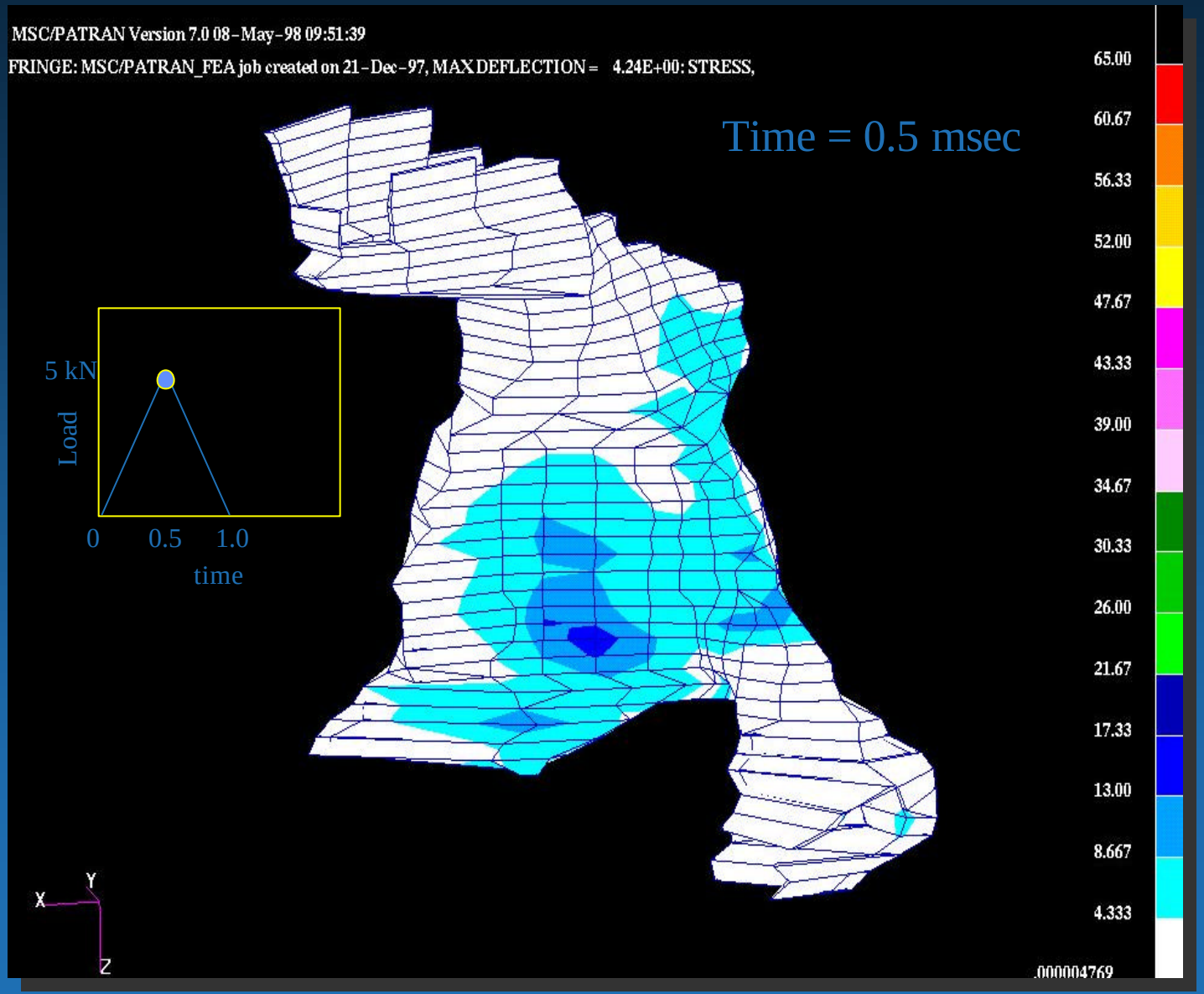
Region of the superior pubic ramus



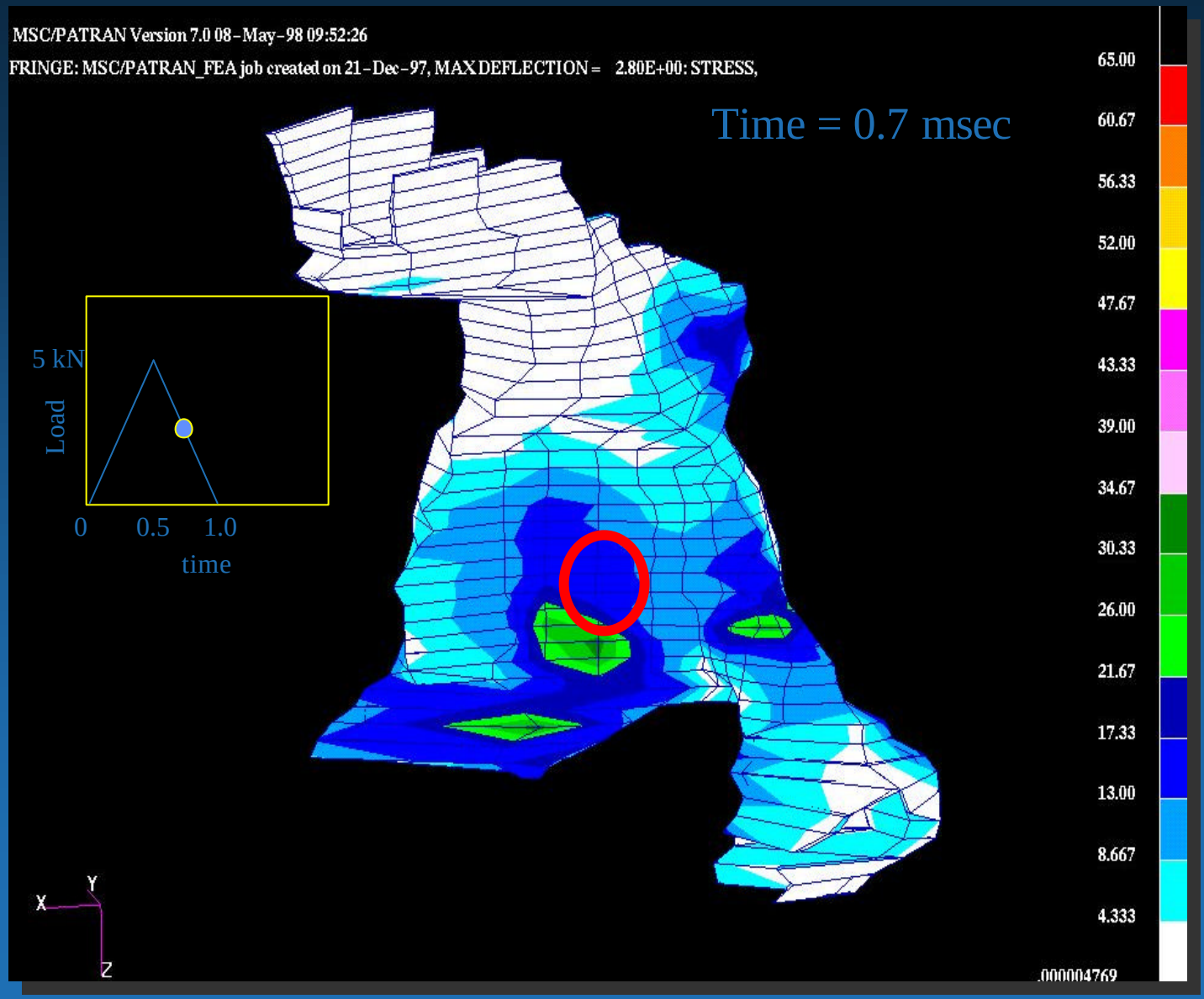
0.5 msec load ramp



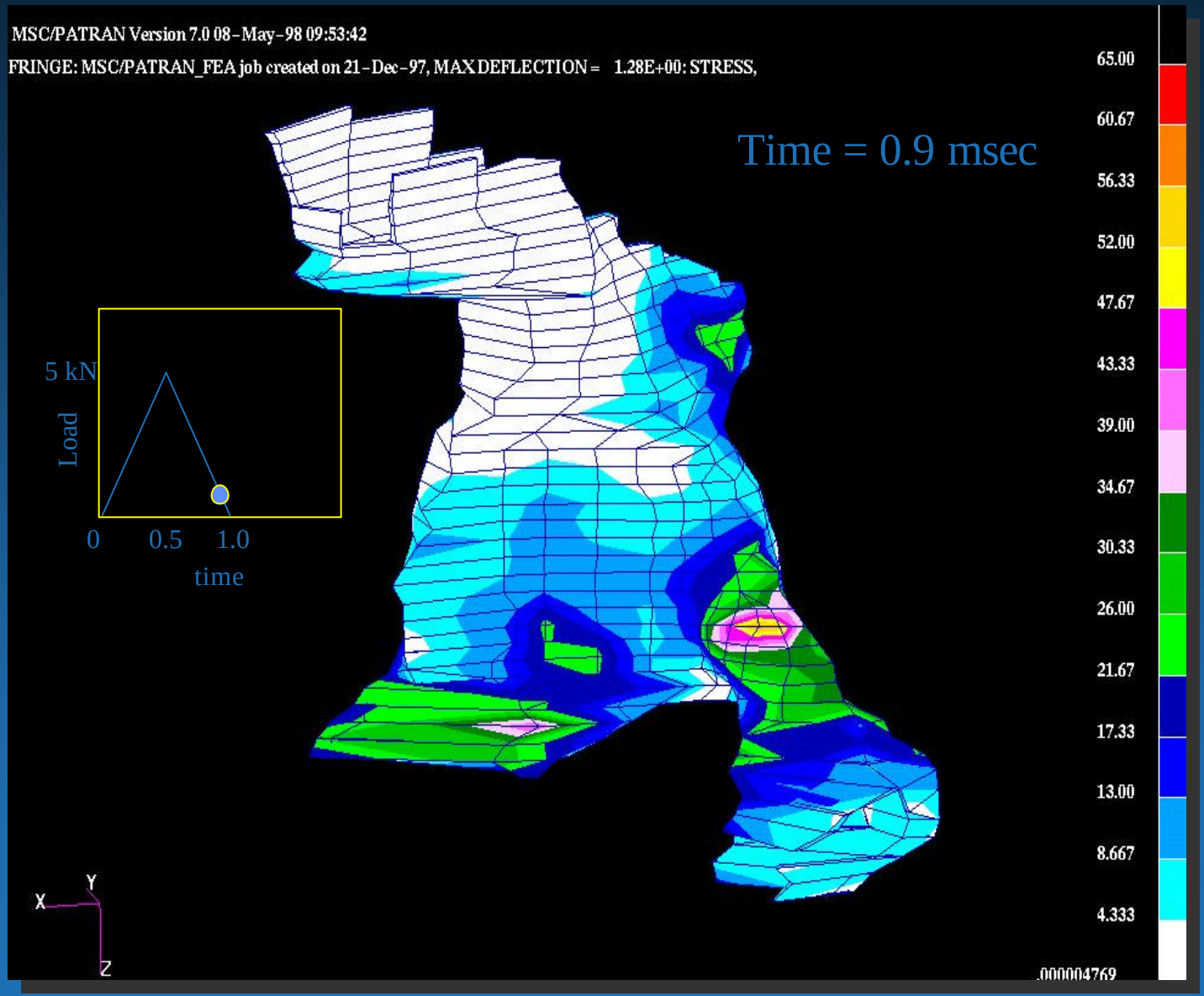
0.5 msec load ramp



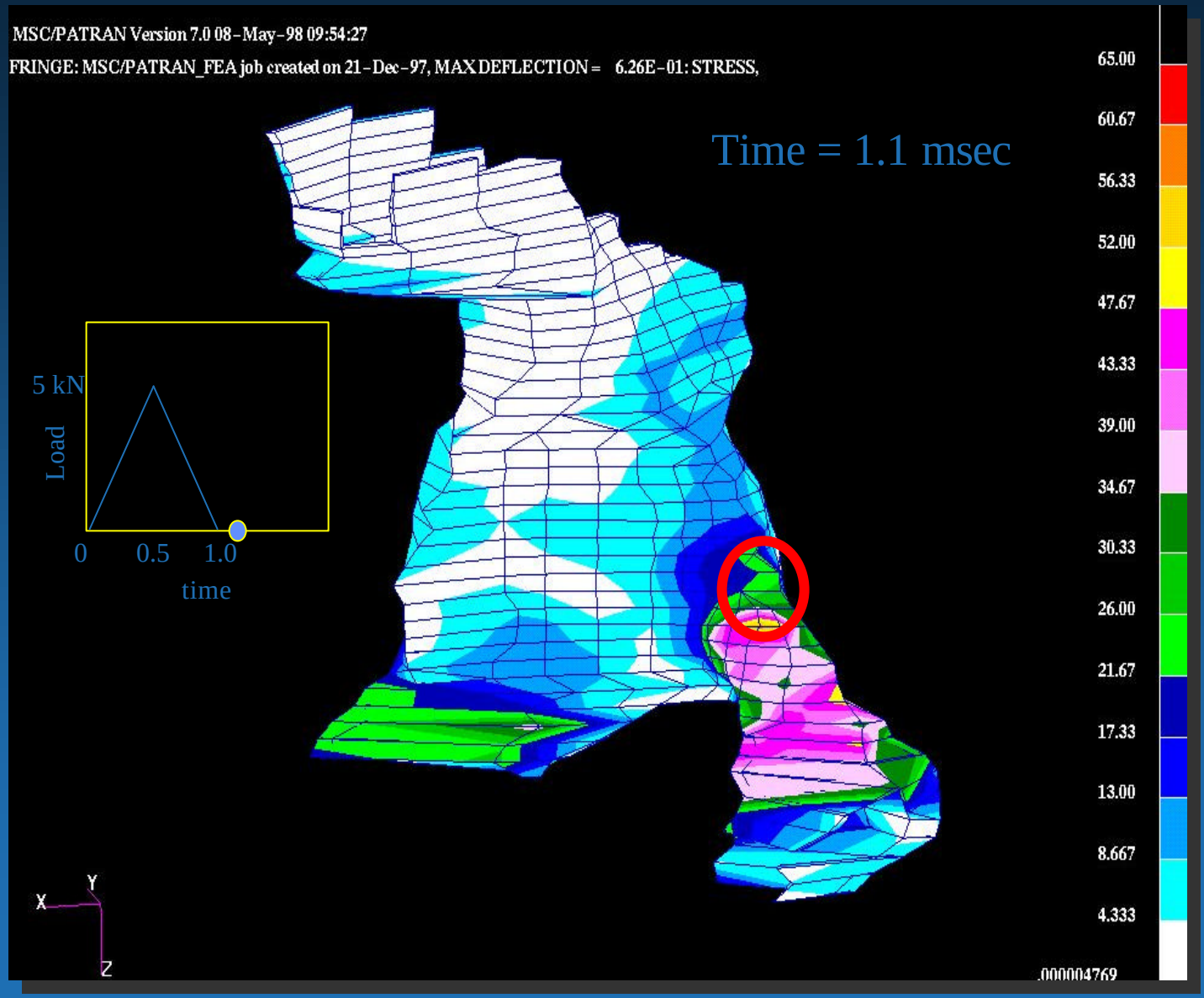
0.5 msec load ramp



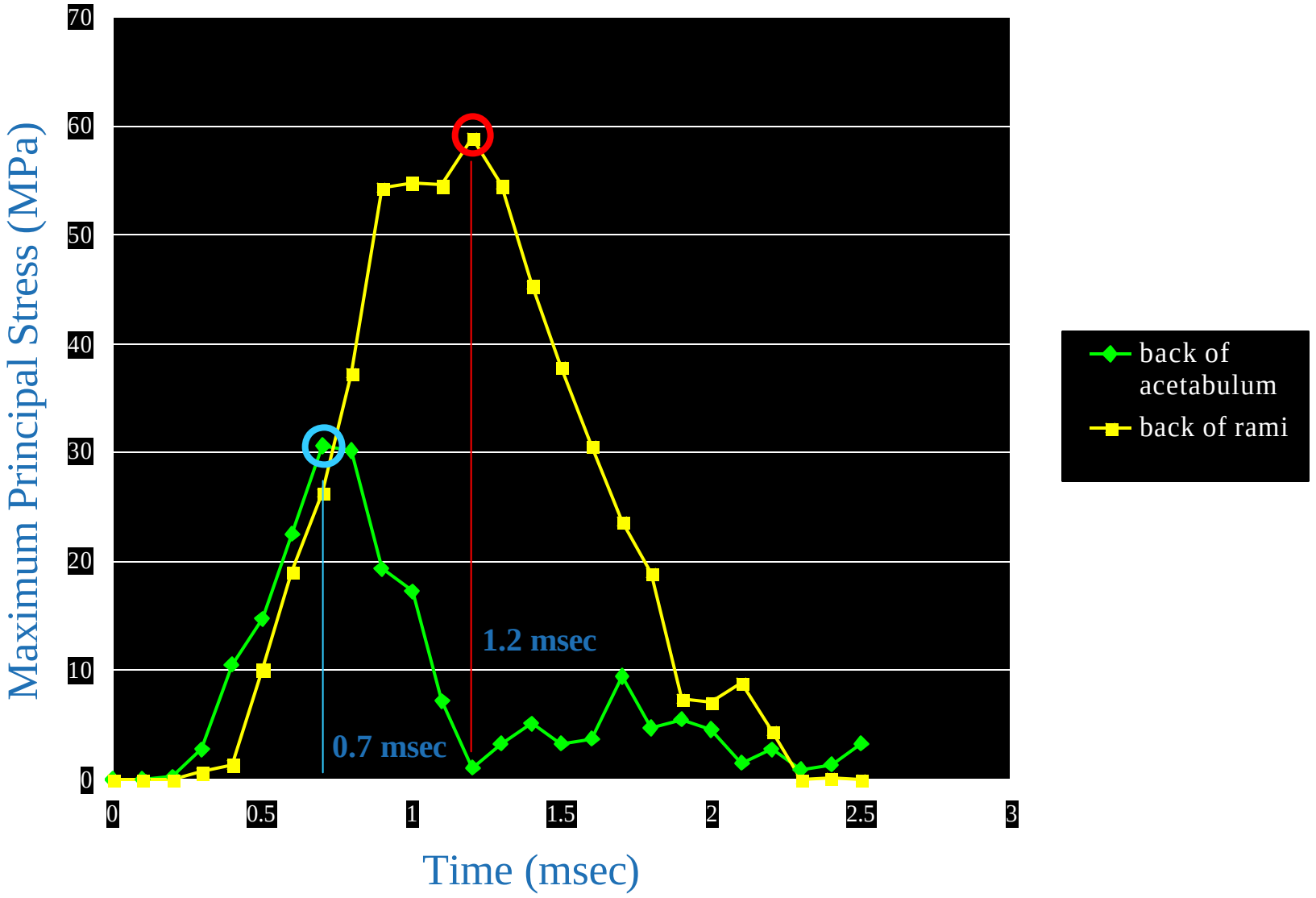
0.5 msec load ramp



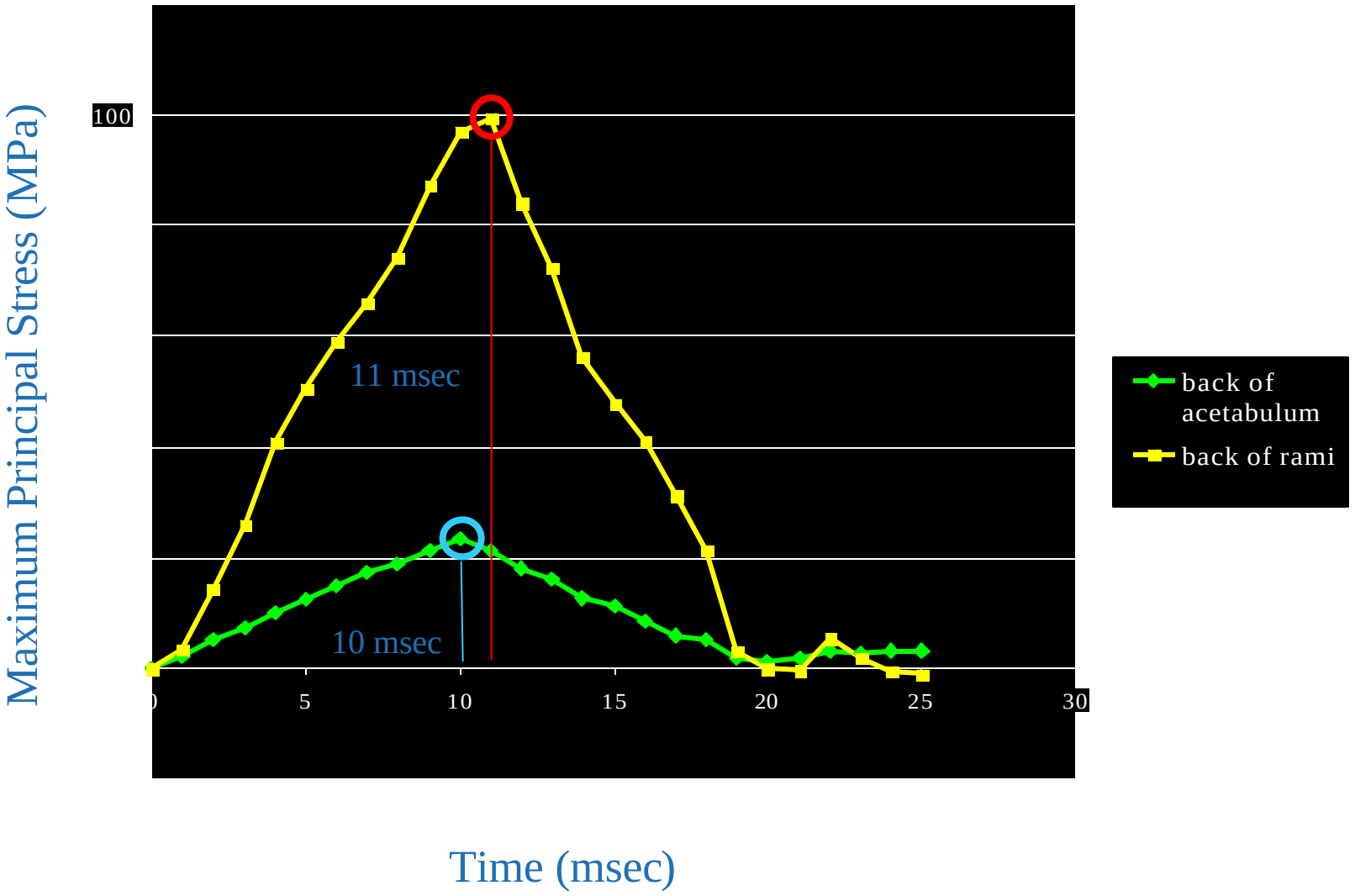
0.5 msec load ramp



0.5 msec Ramp -Wing Support



10 msec Ramp - Full Support

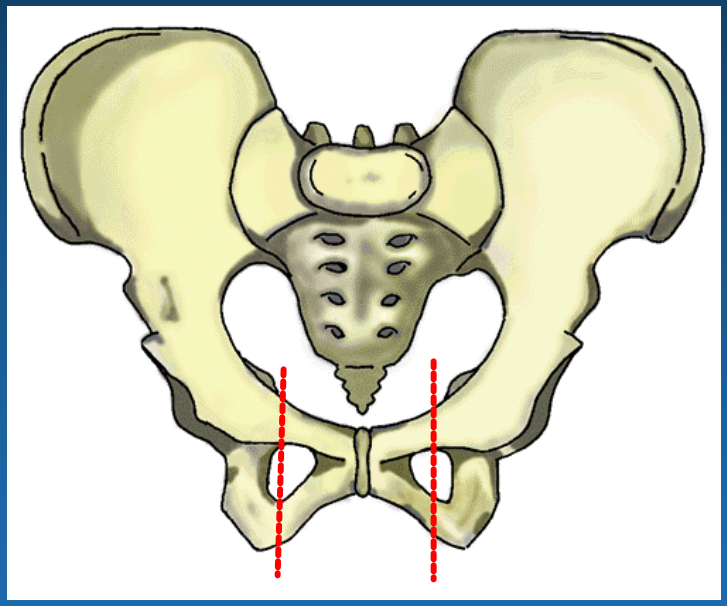


Summary

- Support conditions and loading rate affect resulting fracture type
  - 1 msec loading causes transient stress wave
    - acetabular fx likely
  - 20 msec loading rate results in essentially quasistatic stresses
    - rami fx likely

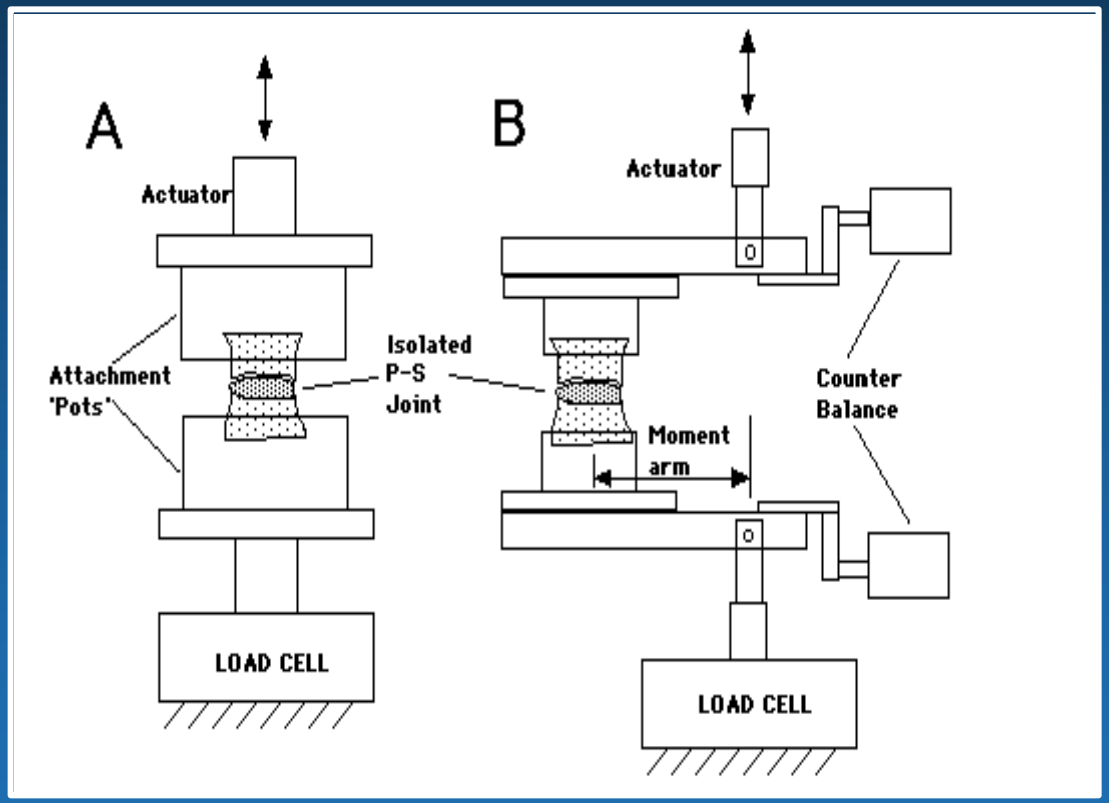
Mechanical Properties of the Pubic Symphysis and Sacroiliac Joints

- Quantify stiffness & viscoelasticity
- Effects of impact on joint properties
- To obtain structural input for FE models

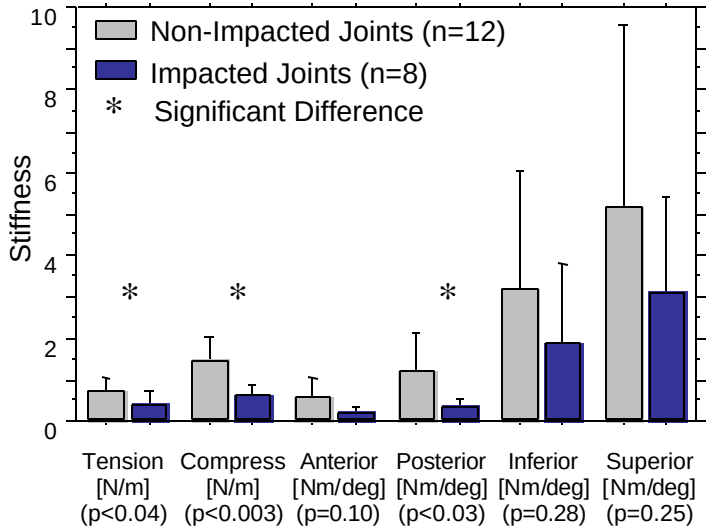


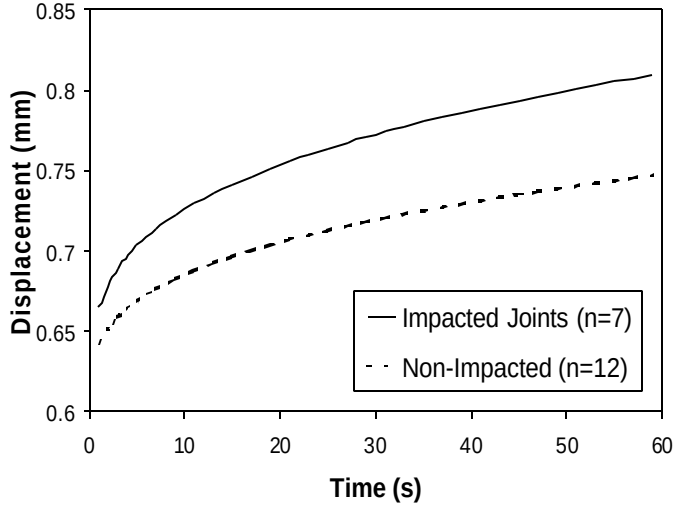
Experiments - PS Joints

- Elastic stiffness
  - tension, compression
  - A/P & S/I bending
- Creep
  - tension
- Impacted vs. non-impacted
- Gender and age



Example Results - PS Joint





Impacted joints consistently more compliant than non-impacted

Impacted joints displayed greater creep rates than non-impacted

Future Directions

- Intervention strategies
  - door interiors, energy absorption, airbags
- Contact stress analysis - pressure film
  - acetabular stresses vs. femoral angle
- Computational modeling
  - Improve biofidelity - incorporate joint stiffness
  - 5th percentile female pelvis