UM-CIREN Side Impact Field Crashes, Injury, & Intrusion

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Side Impacts

- 1,385,000 side impacts[1]
- 13% of all crashes[1]
- 18% of fatal crashes[1]

- Higher risk for
  - Mortality[2]
  - Multiple injuries within body regions[3]
- Occupants more likely to suffer from pelvic fractures[4]

1. *2006 Motor Vehicle Crash data from FARS & GES,* NHTSA
2. Injury patterns associated with direction of impact: drivers admitted to trauma centers, Dischinger PC, Cushing BM, Kerns, TJ. J Trauma. 1993 Sep;35(3):454-8; discussion 458-9.
3. Side impact motor vehicular crashes: patterns of injury, Mikhail JN. Int J Trauma Nurs. 1995 Jul-Sep;1(3):64-9.
4. Risk factors associated with pelvic fractures sustained in motor vehicle collisions involving newer vehicles, Stein DM, O'Connor JV, Kufera JA, et al. J Trauma. 2006 Jul;61(1):21-30; discussion 30-1.

Side Impacts – UMPIRE

- Utilized our unique access to automotive engineering expertise – 2008 Fellows
  - Expansion of frontal impact analysis done by 2007 Fellows
- Morphometric analysis

Study Population/Case Selection

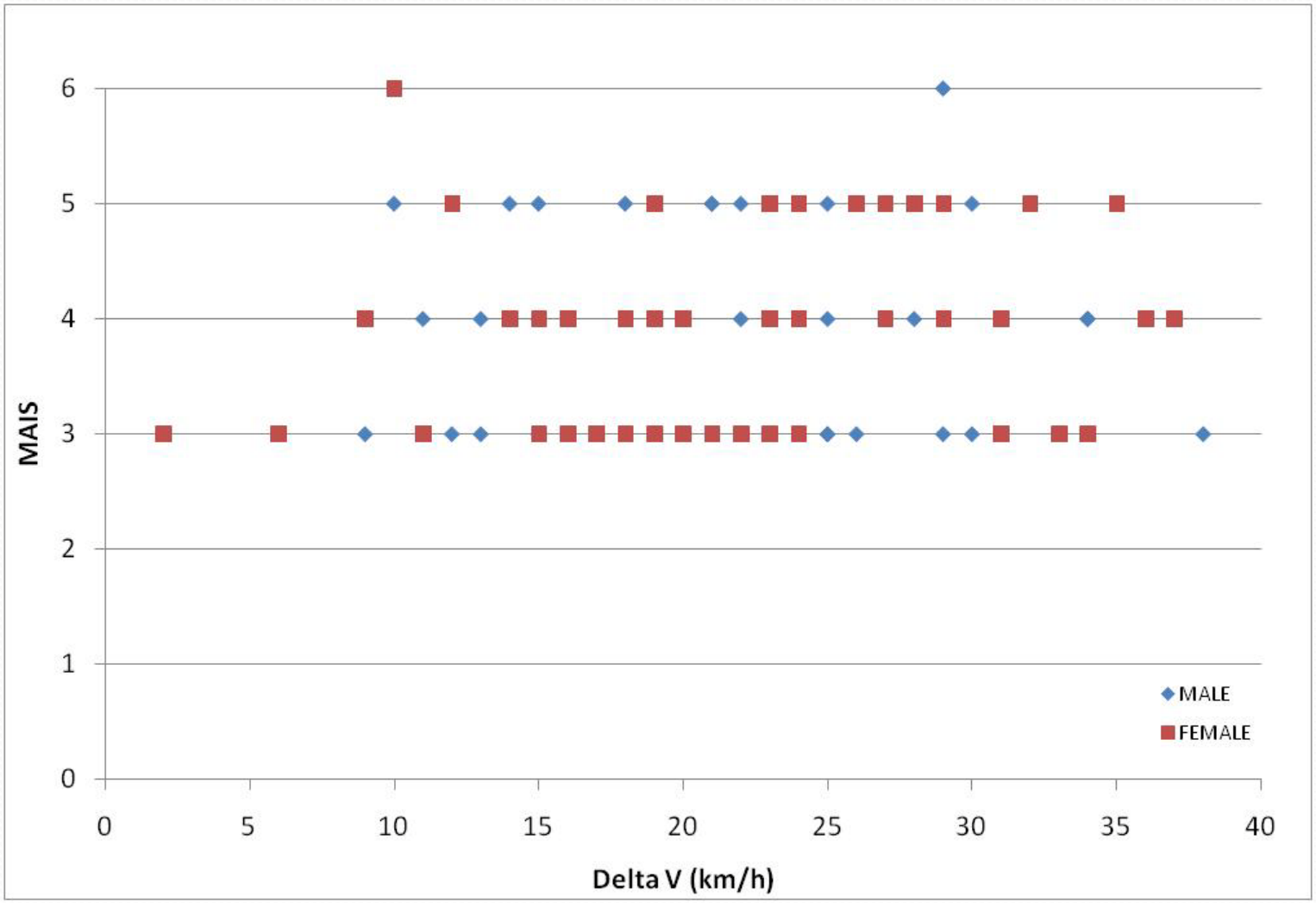
- UM-CIREN Side Impact Cases: 127
- **Side Impact Cases (AIS3+), Vehicle Model Year >= 1997*: 103**
  - 1997 is the first year of 100% implementation of the dynamic FMVSS 214 for passenger cars
  - Limited data for vehicles with inflatable side-impact restraints

- All case occupants are severely injured (AIS 3+)
- Moderate & uninjured population not included

Crash Classification

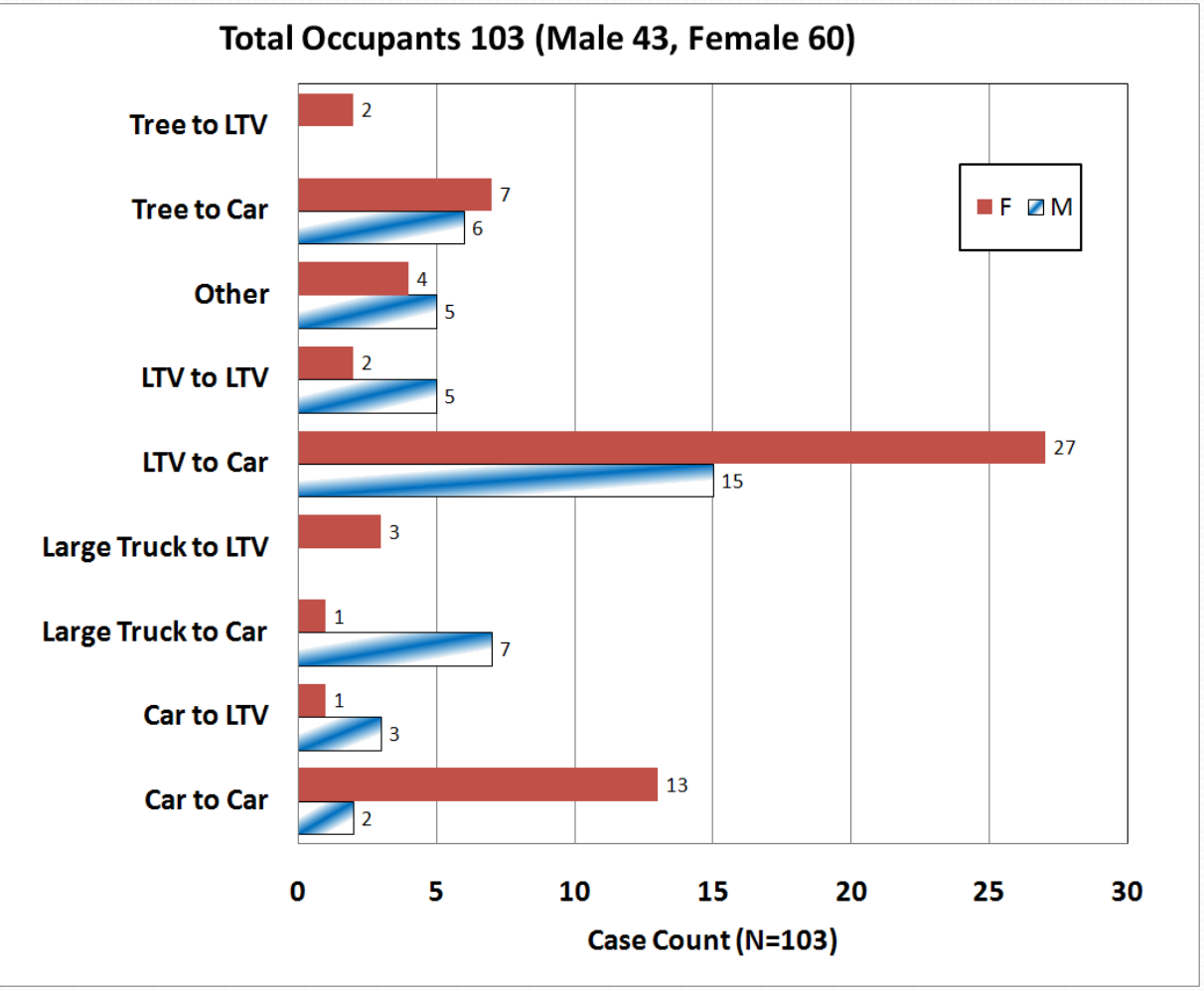
- Initial classifications based on CDC and PDOF
- Reviewed photos for rocker engagement, to classify SNCAP versus IIHS test similarity
- Classified by striking object and case vehicle type
- Documented
  - maximum intrusion
  - maximum crush
  - lateral ΔV

MAIS v. Lateral delta V



Serious injury occurs over a wide range of delta Vs

Striking Object to Case Vehicle by Gender

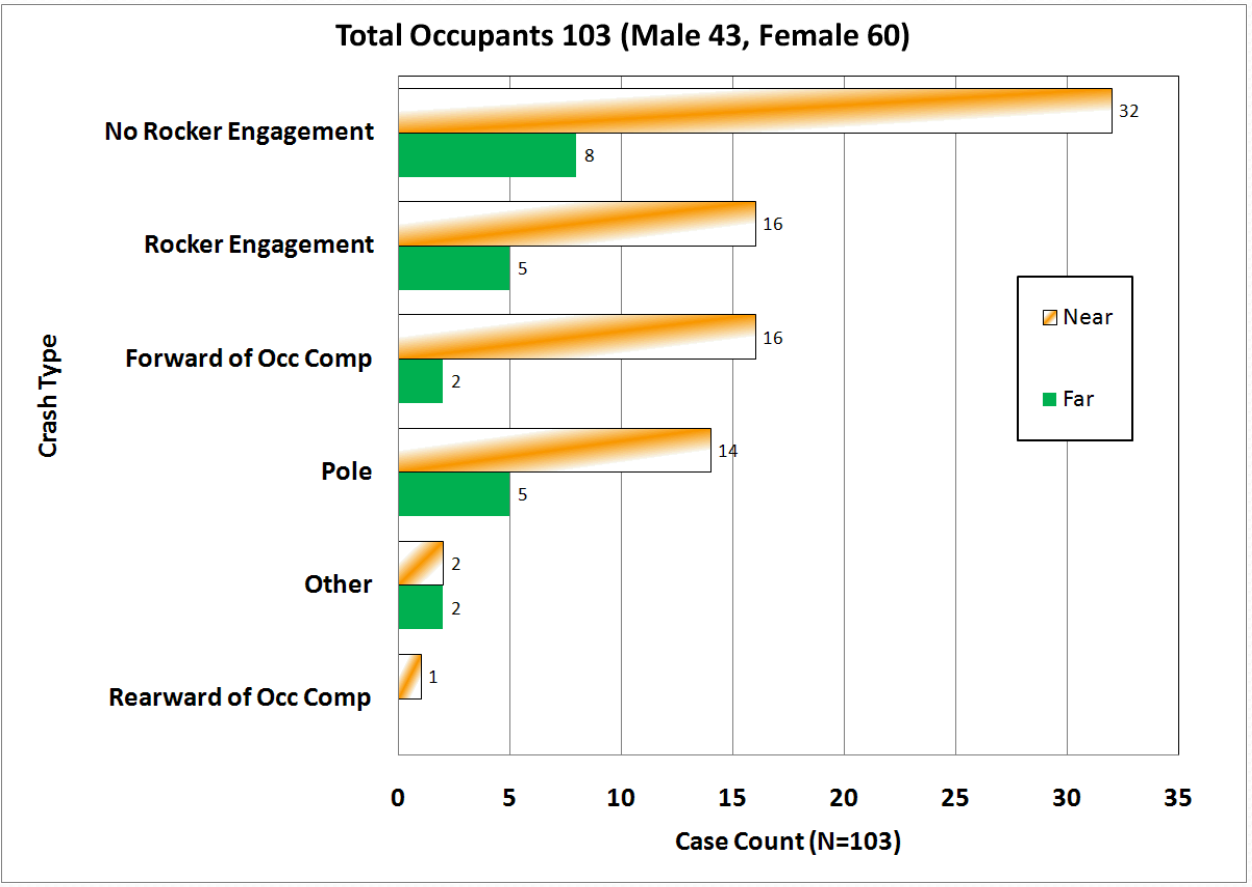


- 41% of cases were LTV to car
- 15% of cases were car to car
- 15% of cases were tree/pole impacts

- 83% of case vehicles are passenger cars

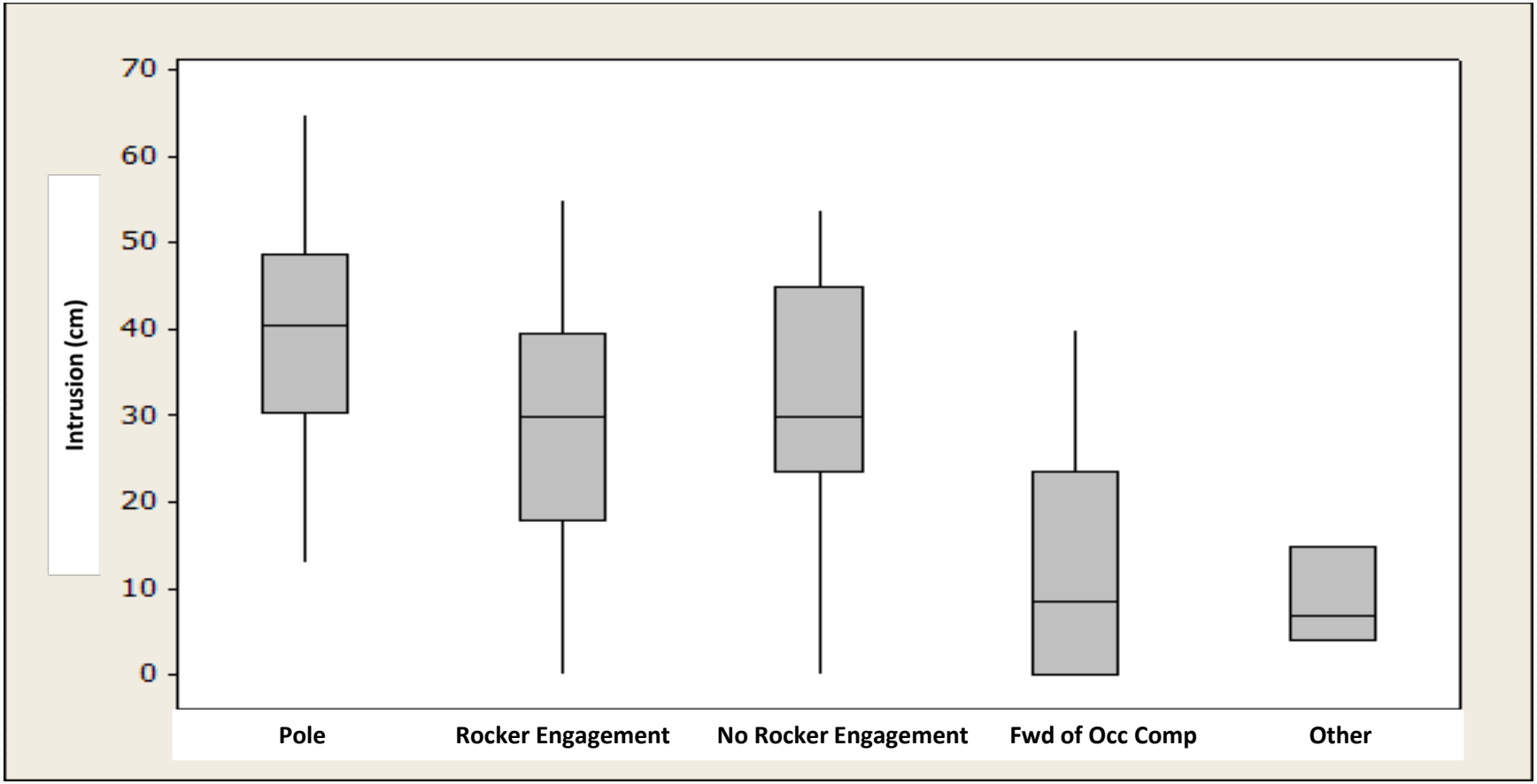
- Females were over represented in the LTV to Car and Car to Car categories

Crash Type Classification Results



- 60% of side impacts similar in **configuration** to current lab tests
  - Crashes to the occupant compartment with near side occupants, similar in configuration to IIHS, SNCAP, and Pole tests
- 21% of cases are far side occupants
- 17% of side impacts are centered forward of the occupant compartment

Average Local Intrusion by Crash Configuration-Near-Side Occupants

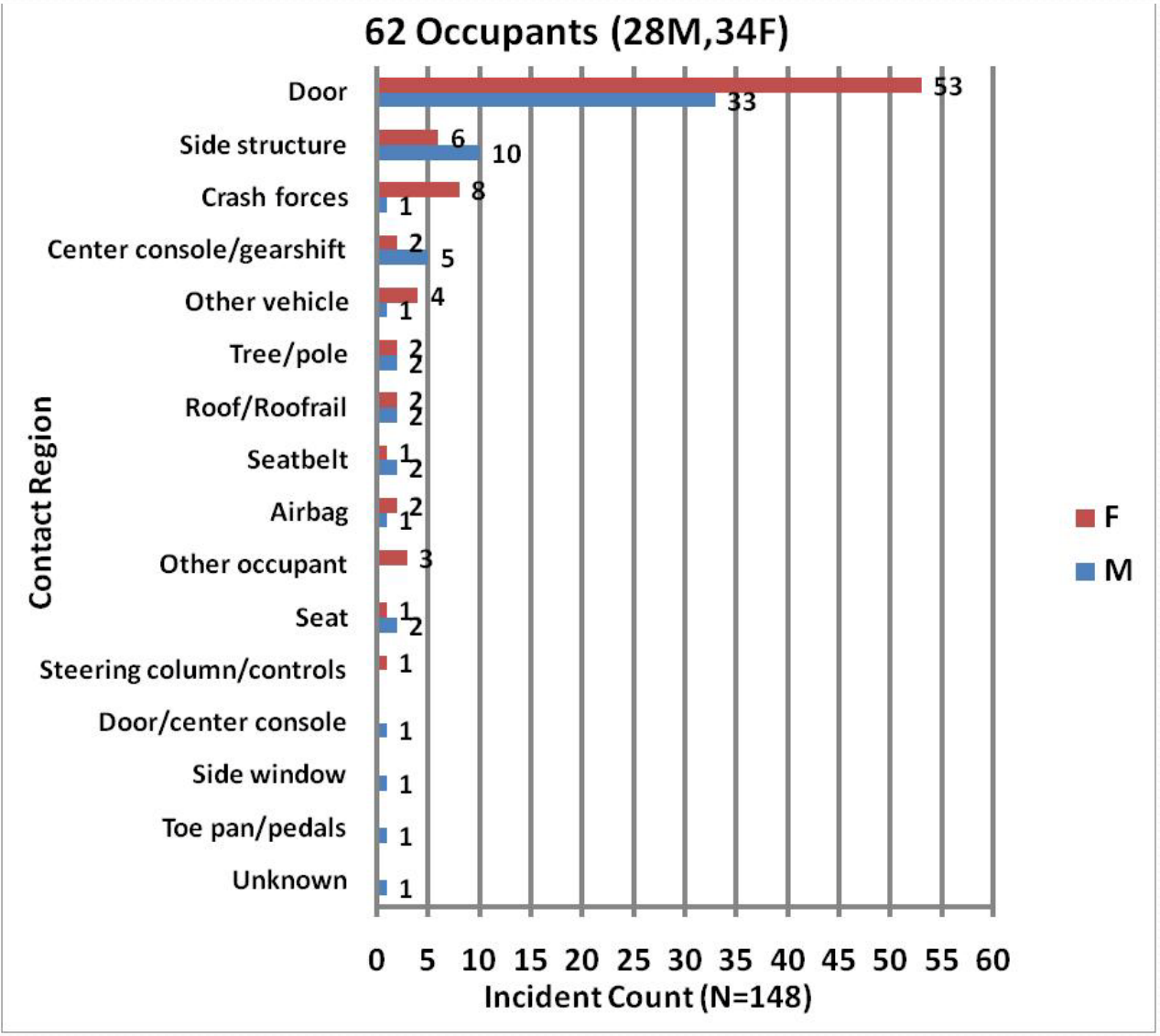


- Pole type impacts had the greatest average local intrusion.
- Using Analysis of Means, the average local intrusions of Pole, IIHS and SNCAP are statistically the same (95% confidence)

Injury Patterns & Occupant Factors

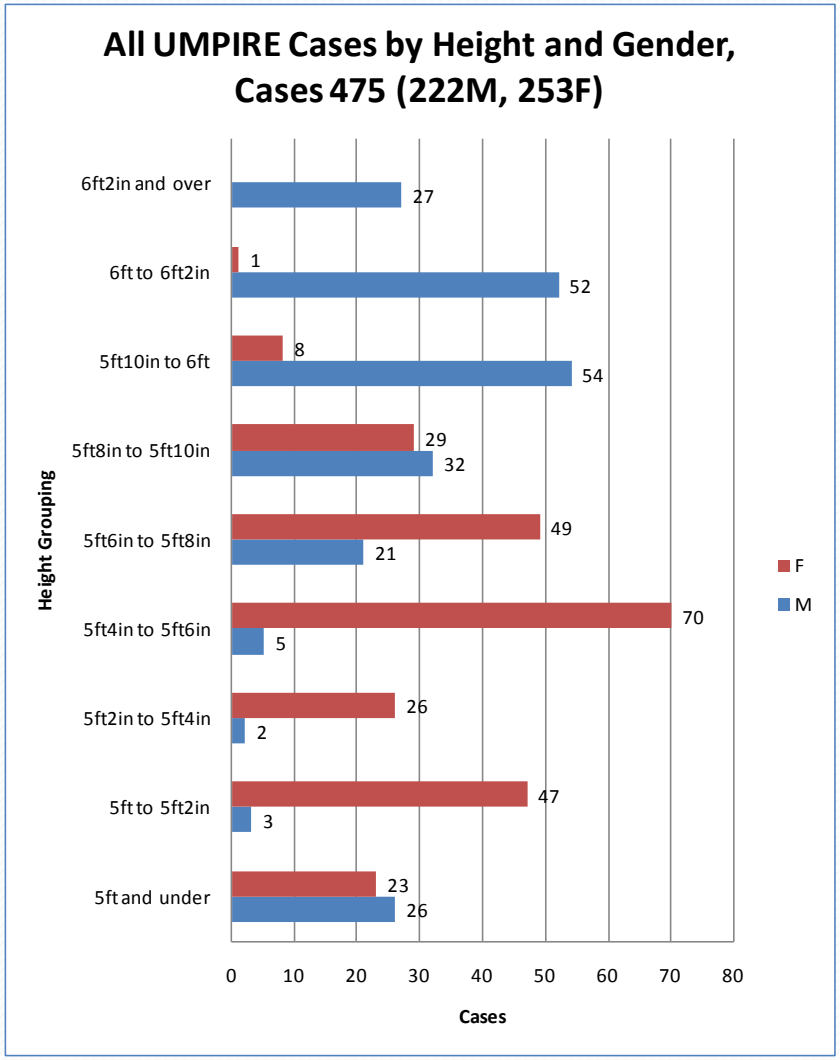
- Investigated near side occupants in crashes similar to IIHS, SNCAP, or Pole Lab tests
  - Contact Location
  - Gender
  - Height
  - Age
  - BMI
  - Injured Body Region

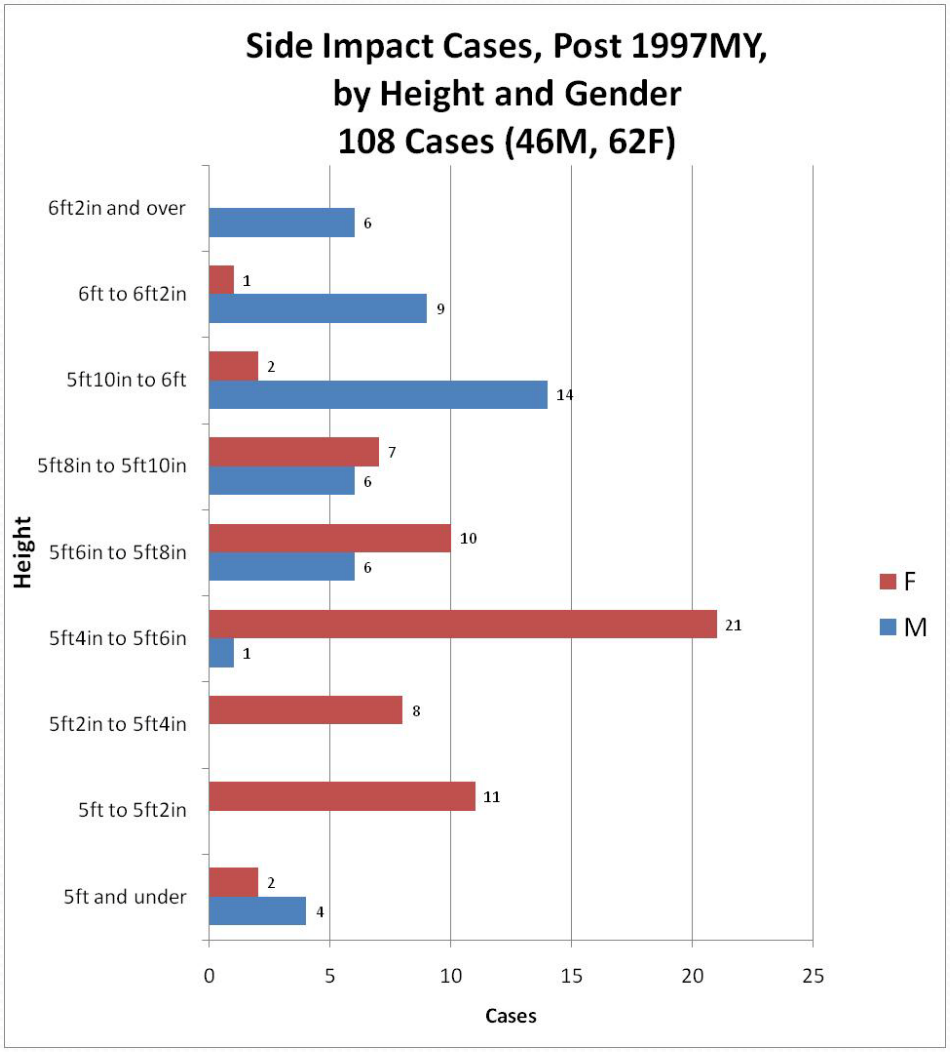
Injury Contact Locations, by Gender



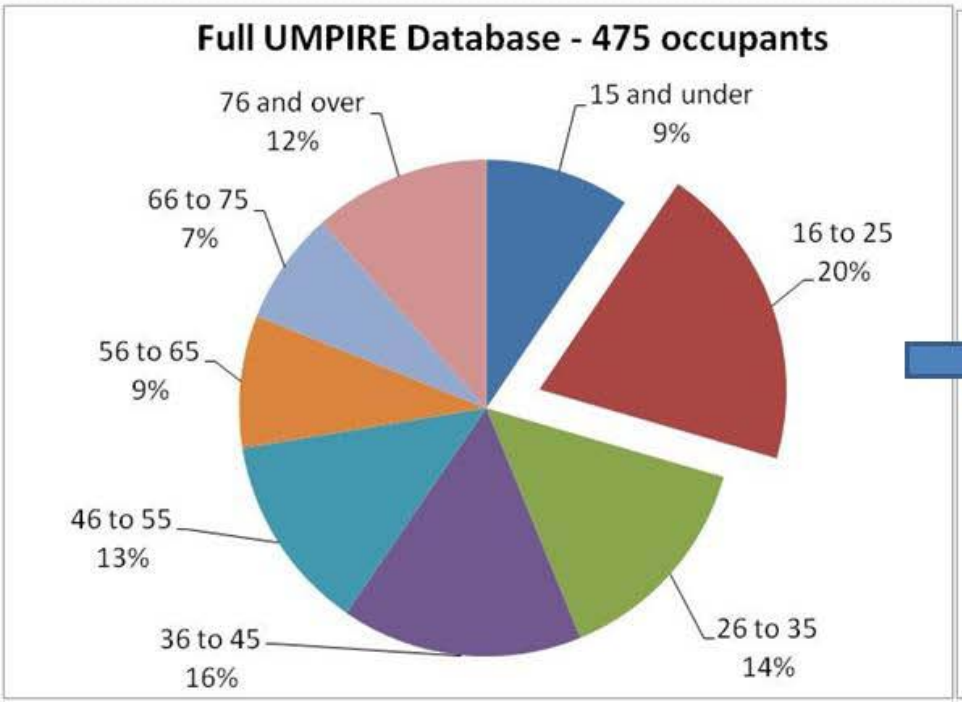
- Majority of injuries assigned to door contact, as expected

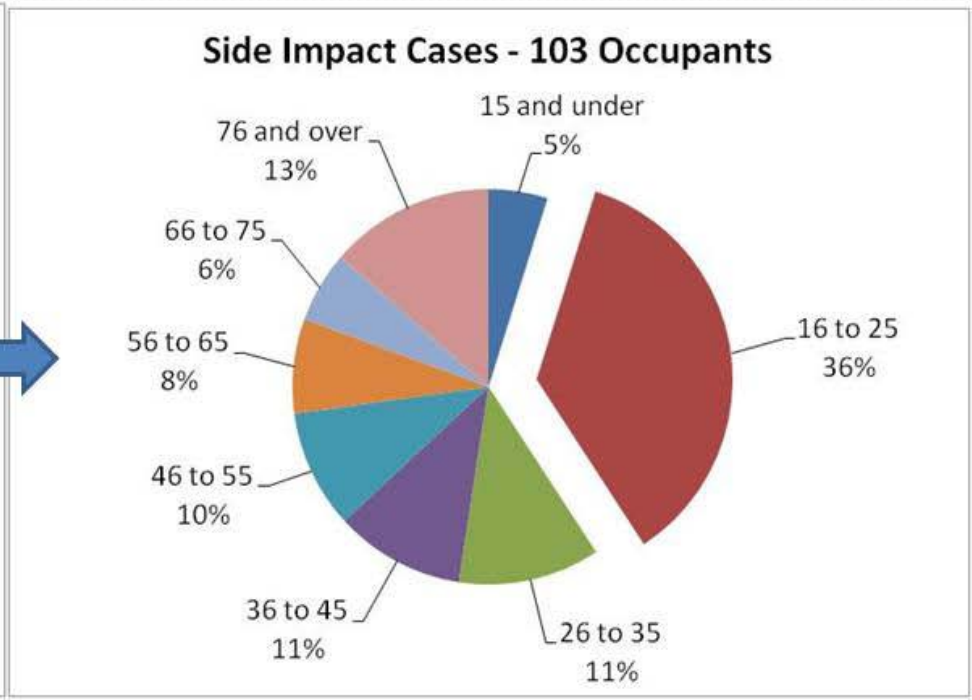
Gender in Side Impact by Height





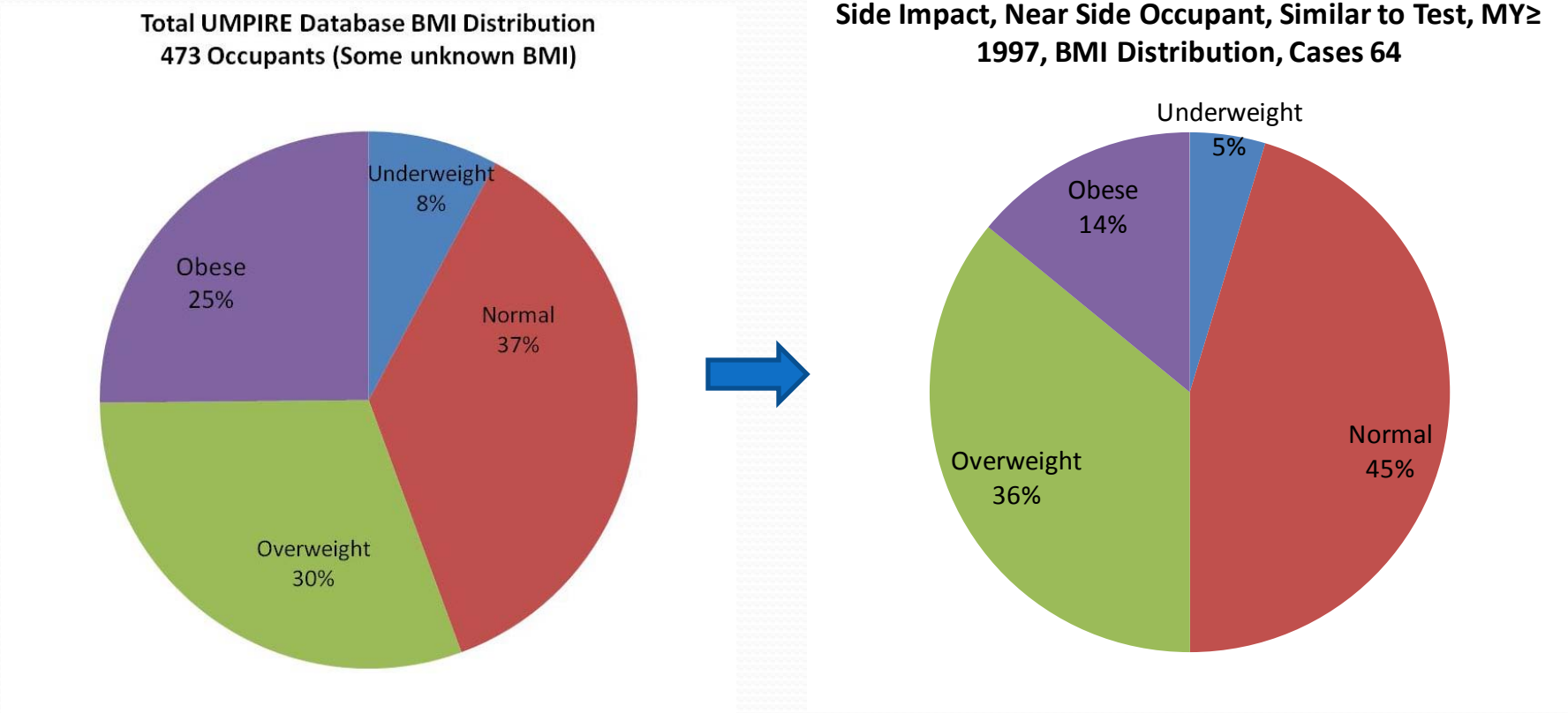
Age Distribution





- High proportion of young adults in the side impact dataset suggests that the frailty associated with aging is not a major factor in this analysis

Cases Similar to Crash Tests-Near Side Occupant: BMI Trends

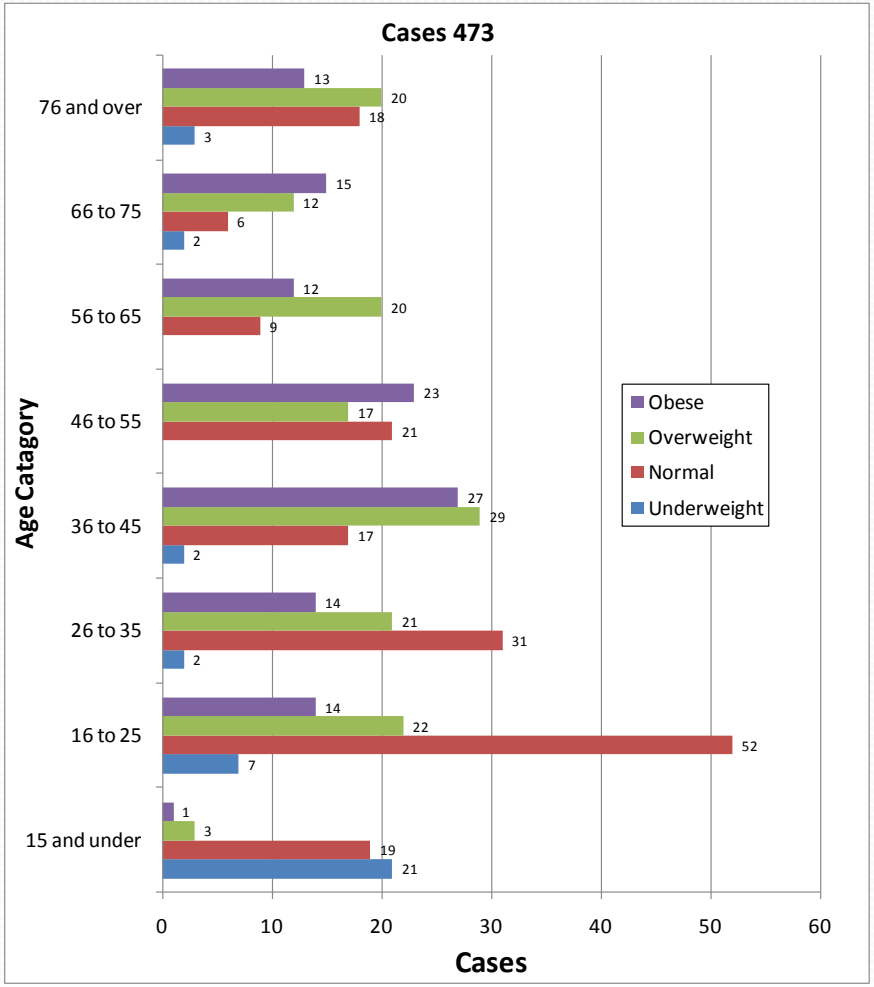


Compared to all crash cases, near side impact cases show that:

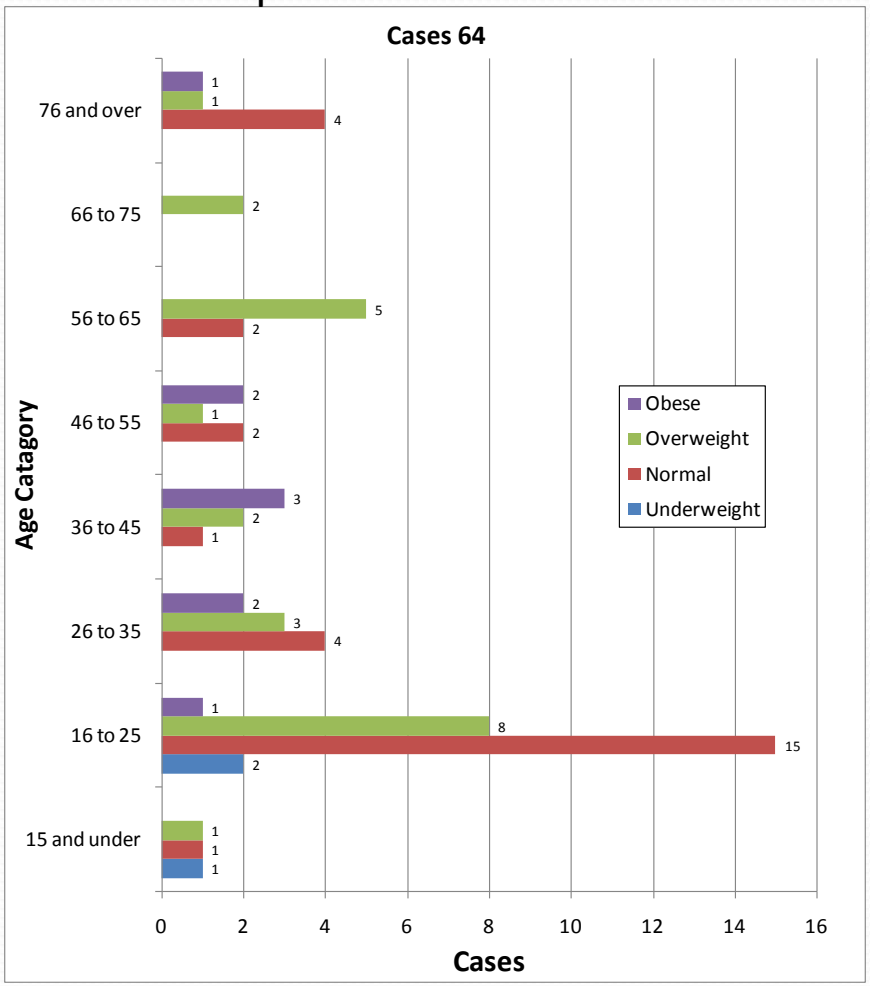
- percentage of normal BMI cases has increased
- percentage of obese cases has decreased

Cases Similar to Crash Tests: BMI Trends by Age

All Cases

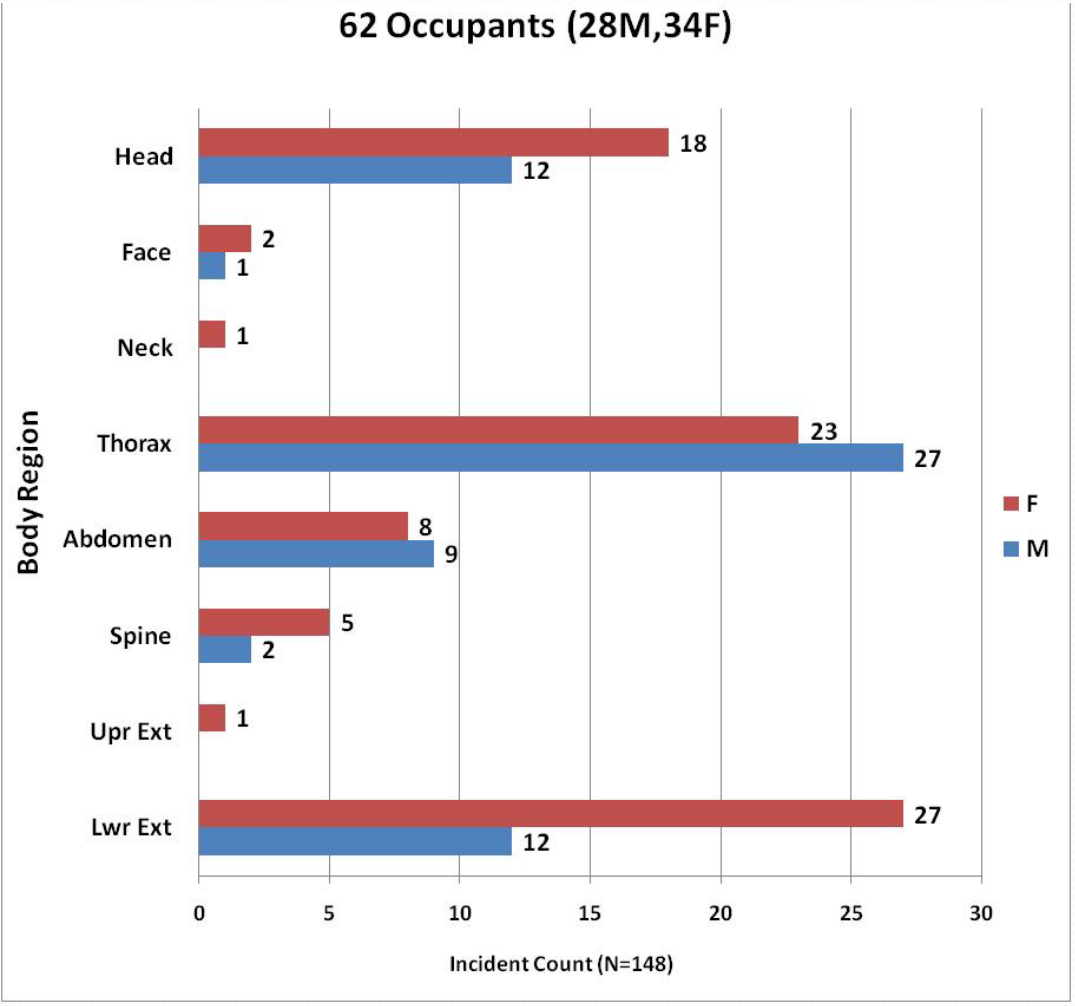


Near Side Impact Cases



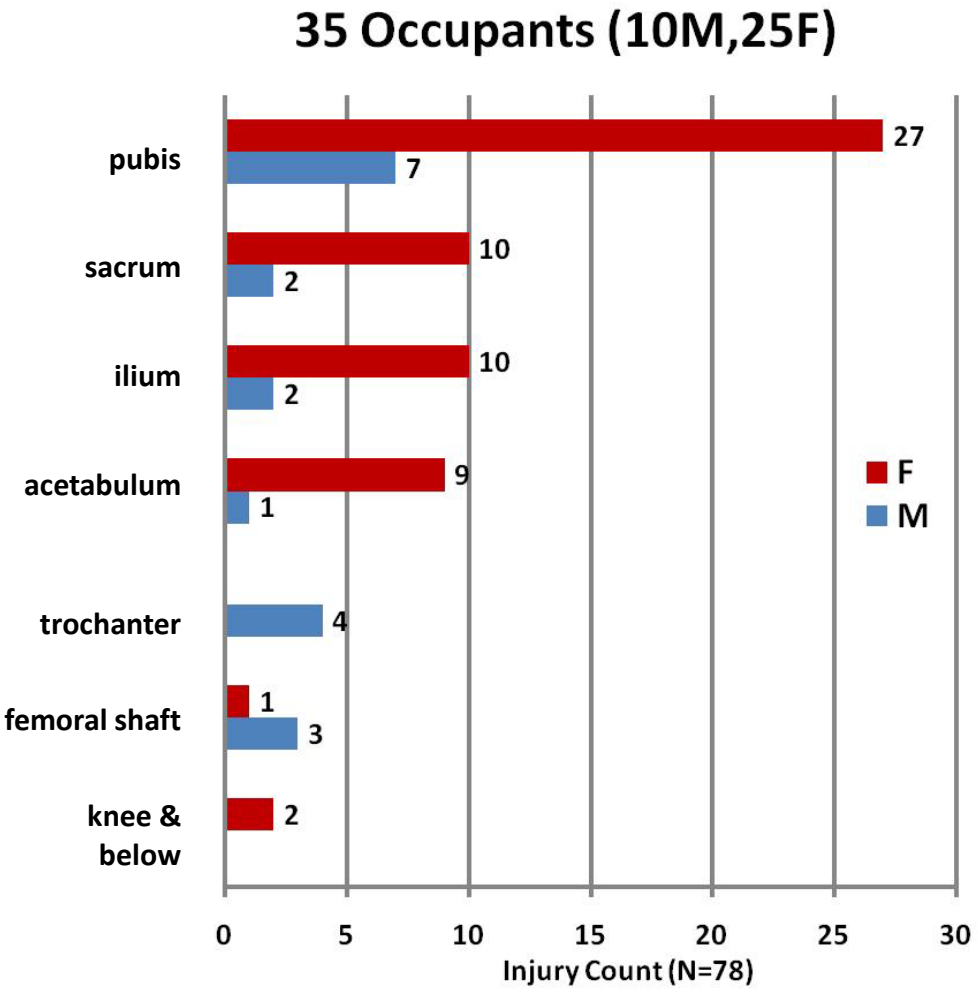
- The higher percentage of Normal BMI in side impacts relative to the full database is linked to the higher occurrence of Normal BMI in the 16 to 25 year old age category

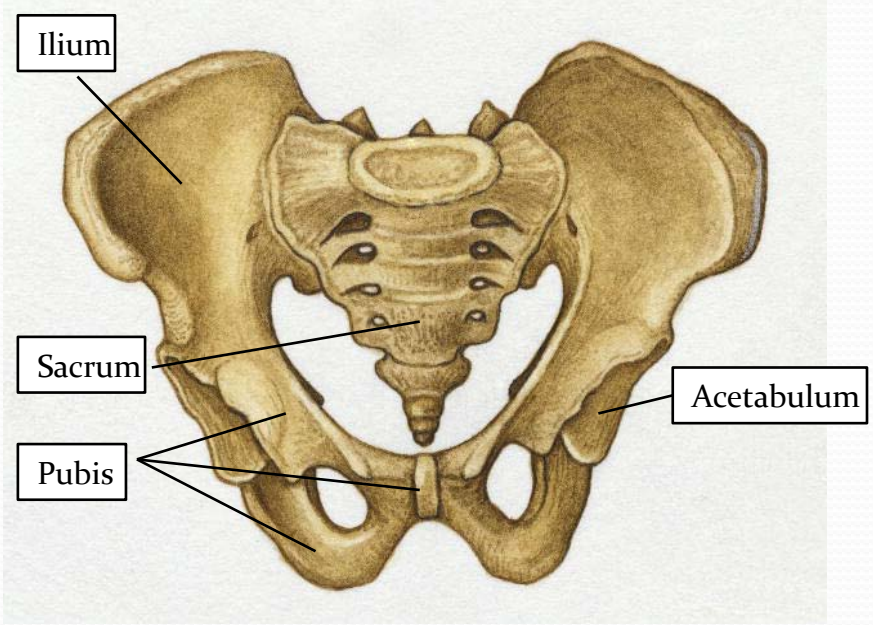
Near Side Occupant: Body Region Injury (AIS3+) Trends



- 3 most commonly injured body regions are the thorax, lower extremities and head
- Females are over-represented in lower extremity injuries

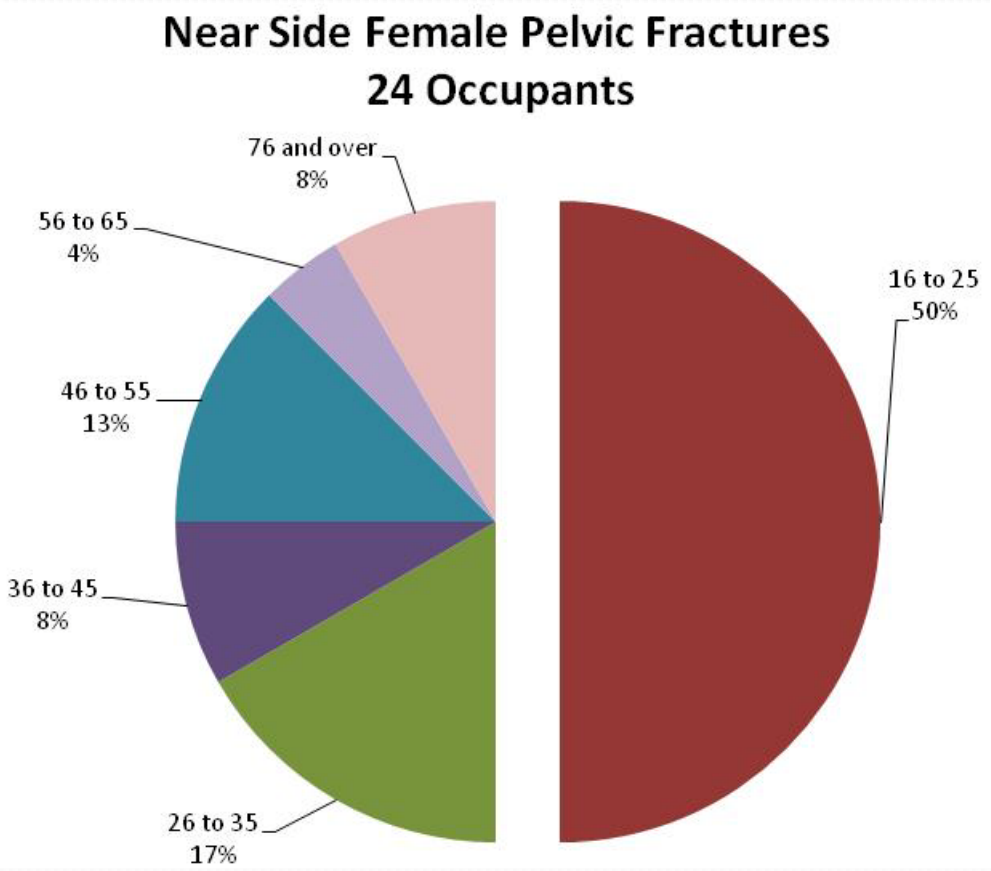
Specific LEX Injuries (AIS3+) Near Side Occupant by Gender

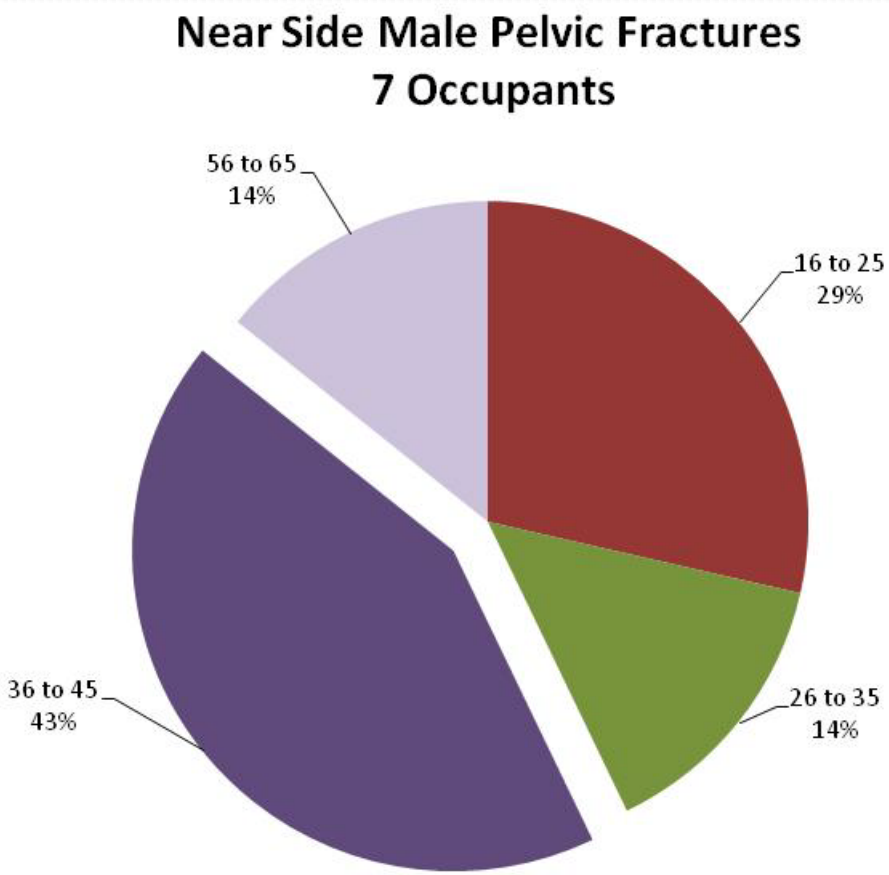




- Most lower extremities injuries involve pelvis
- Females have more pelvic injuries in all parts of the pelvis
- The pubis is the most frequently injured

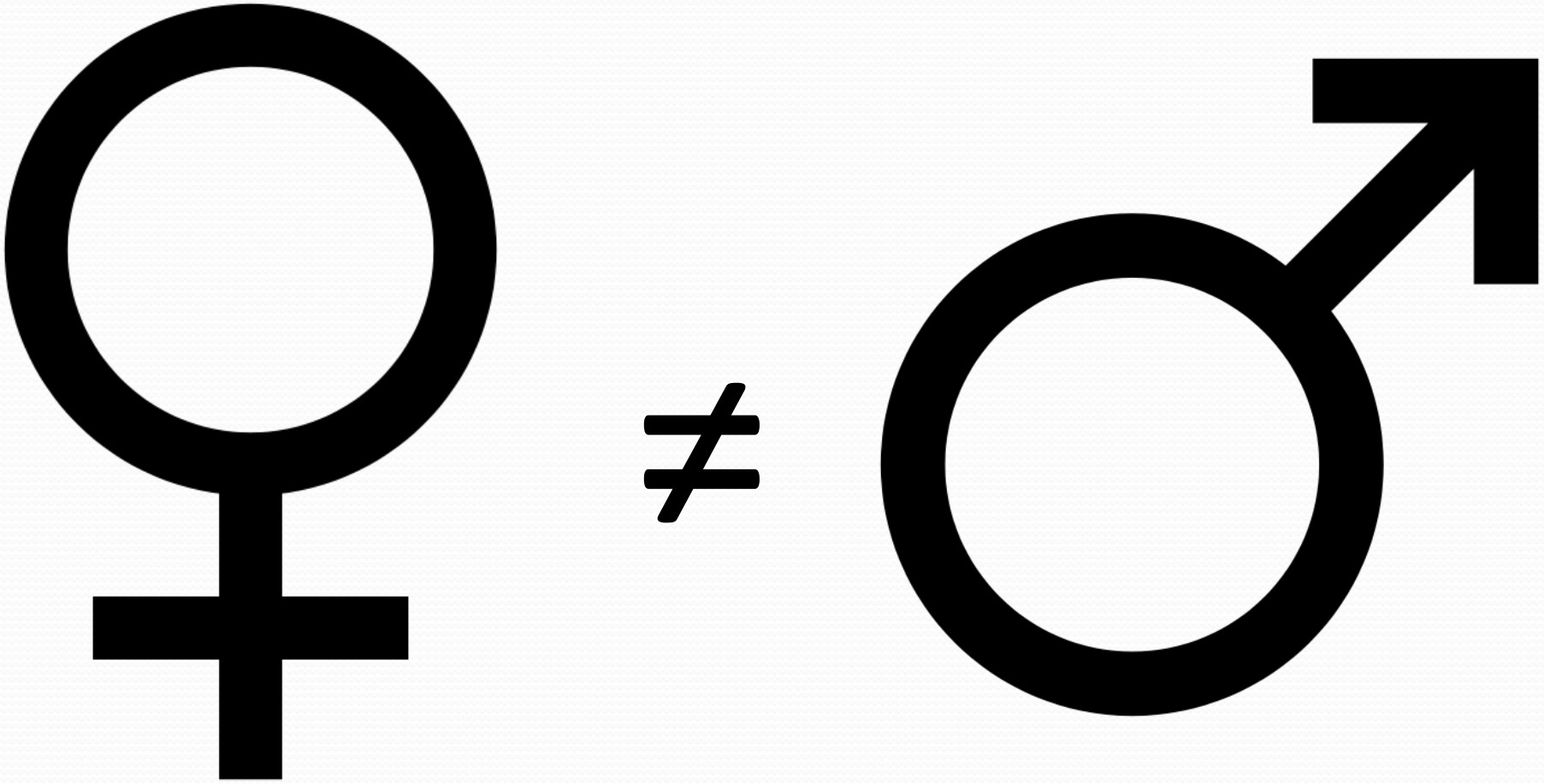
Near Side Occupant: Pelvic Injuries by Age & Gender



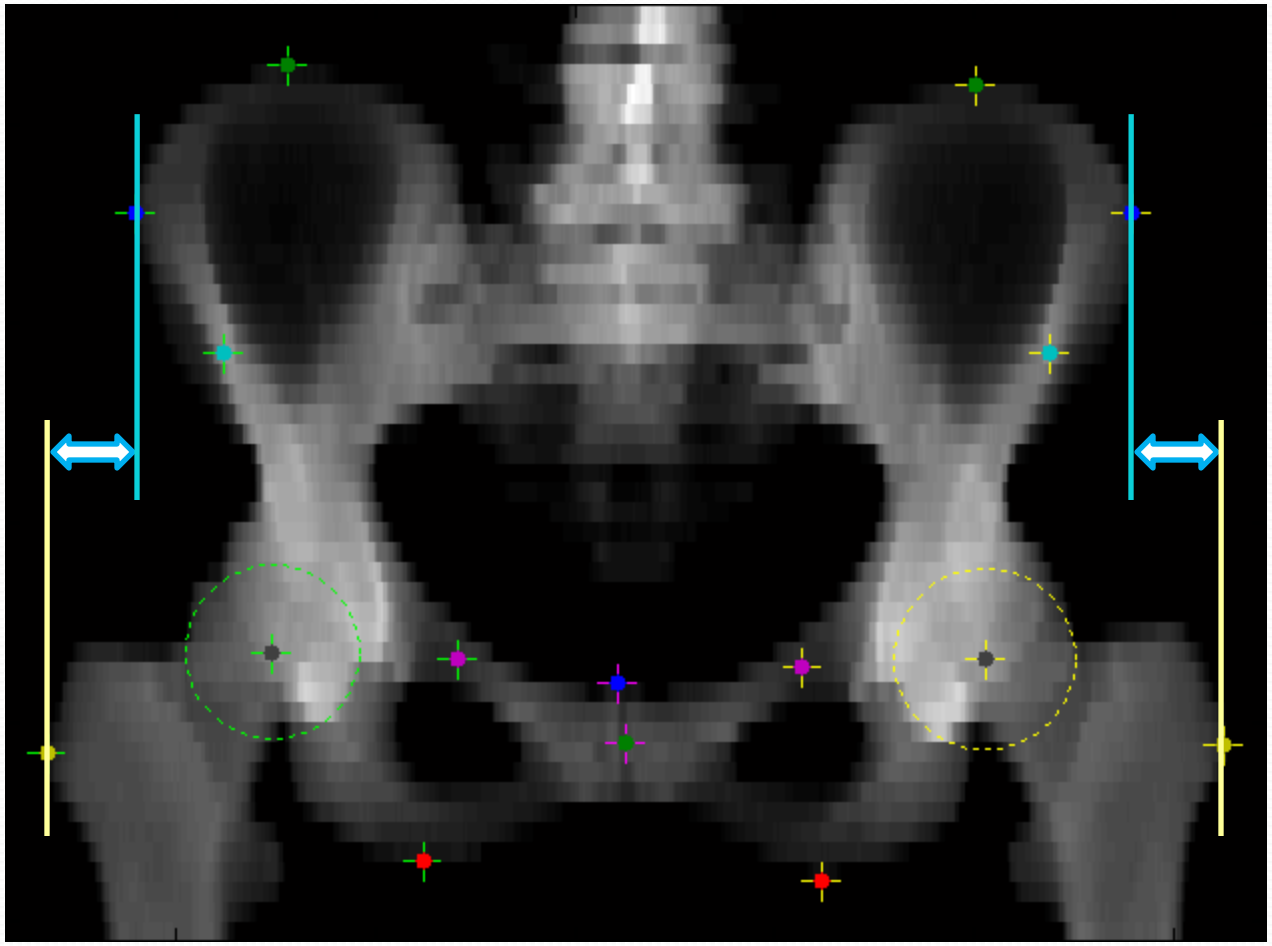


For females, the largest percentage of pelvic injury cases involved 16-25 year olds

This Just in …

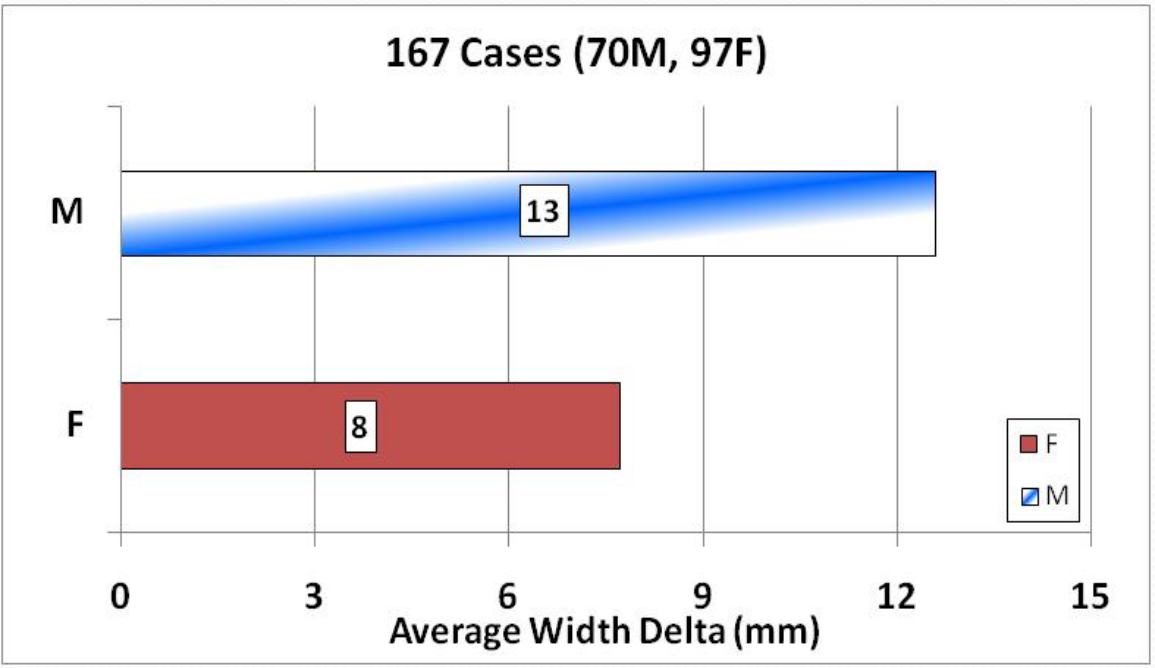


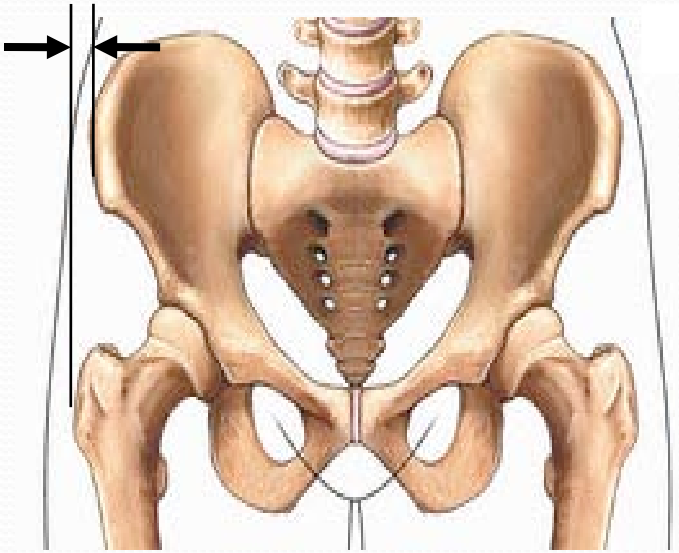
Pelvic width measurement



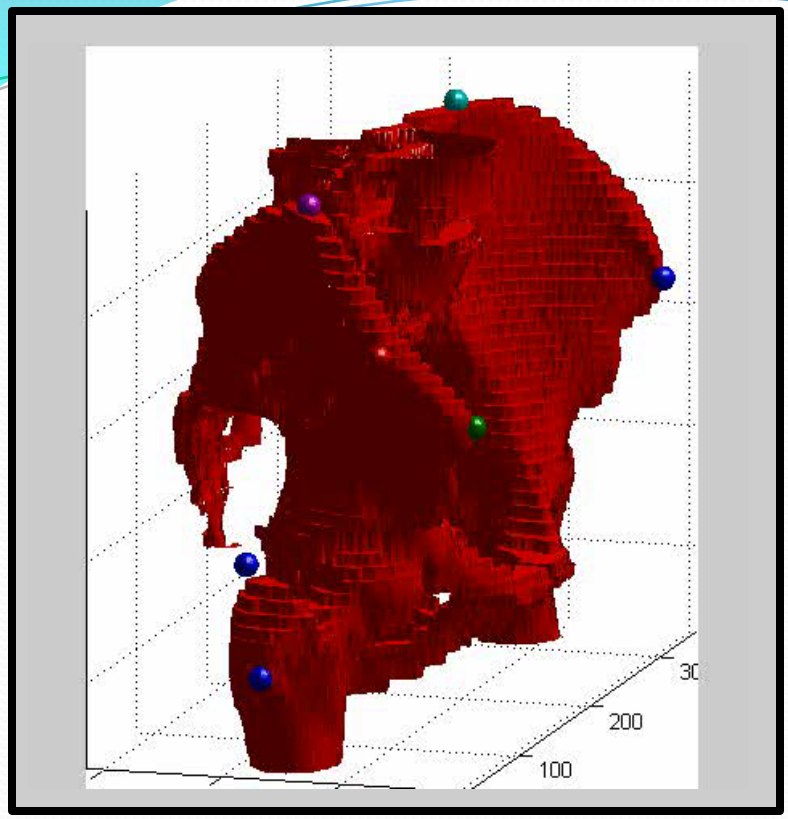
- Pelvis frontal X-Ray image (reconstructed from CT)
- Identify lateral-most pelvic wing points
- Identify lateral-most trochanter locations
- Measure differences, left and right

Anatomic Factors Affecting Pelvic Injury: Iliac Crest to Greater Trochanter Distance





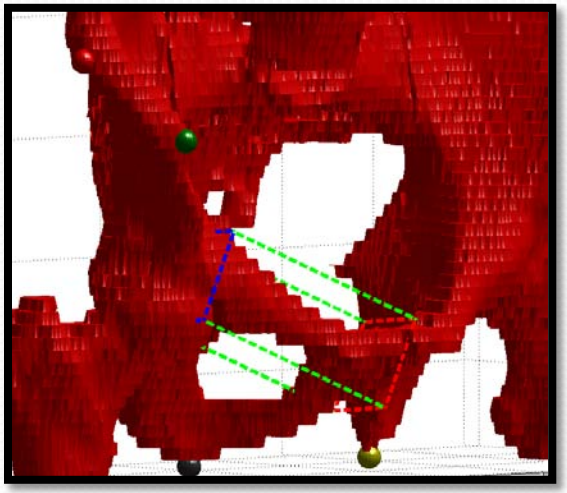
- The lateral distance from the iliac wing to the greater trochanter is larger for males than females (95% confidence, $P<0.001$)
- Possibly contributing to different load paths through the pelvis
- Same trend observed in over 1400 non-CIREN trauma patients



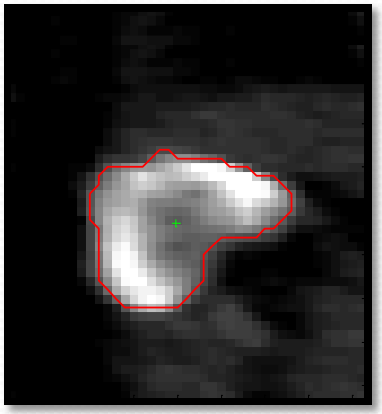
Automatic landmark points

- Pelvis
- sacralTipPt
- LwingLateralmostPt
- RwingLateralmostPt
- LwingSuperiormostPt
- RwingSuperiormostPt
- LischiumInferiormostPt
- RischiumInferiormostPt
- LantSupIliacSpinePt
- RantSupIliacSpinePt
- PubisCentralPt
- RgTrochanterLateralmostPt
- LgTrochanterLateralmostPt

Load in a local volume (oriented along pubic rami)

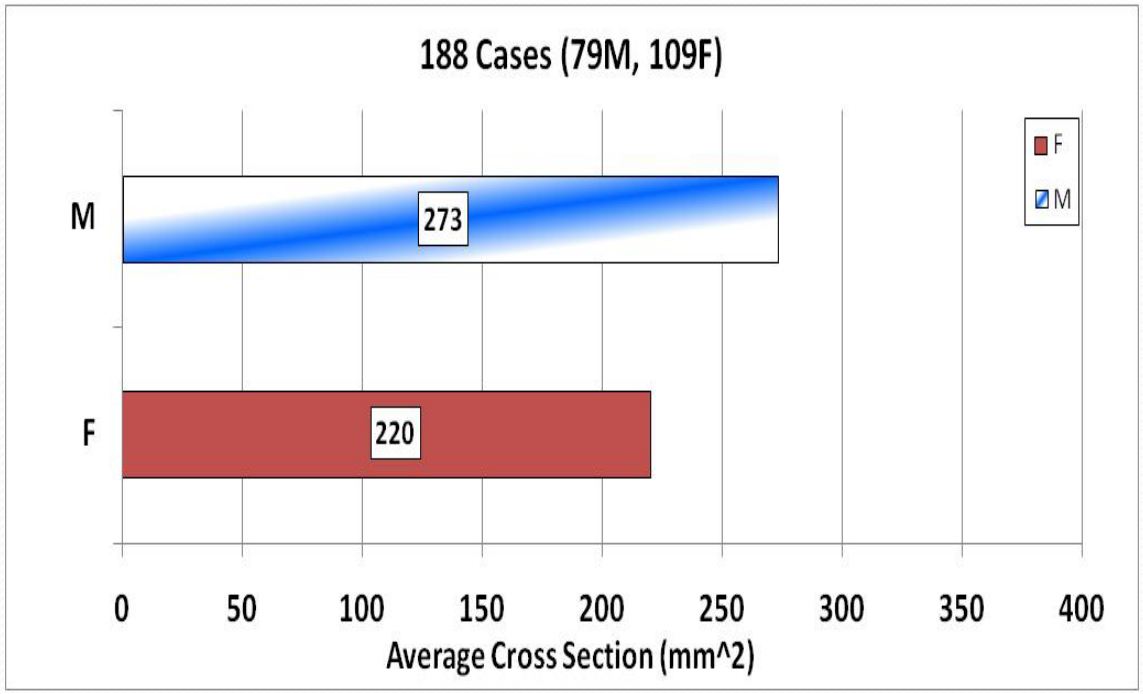


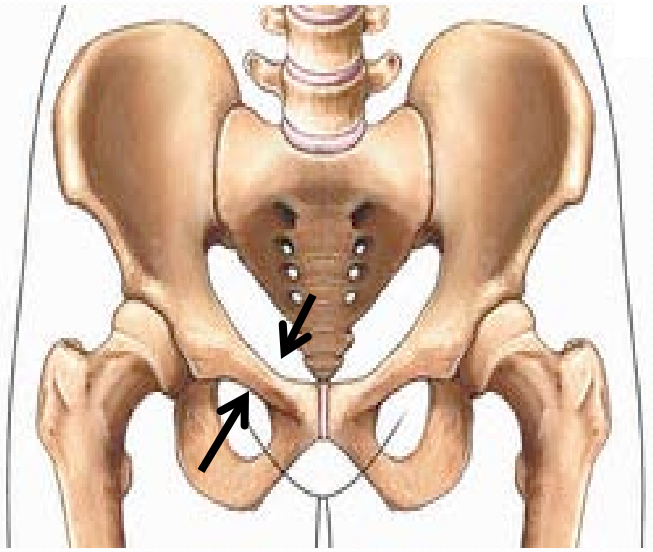
Perpendicular cut through pubic rami shows X-section



Bone X-sectional area = 299mm^2

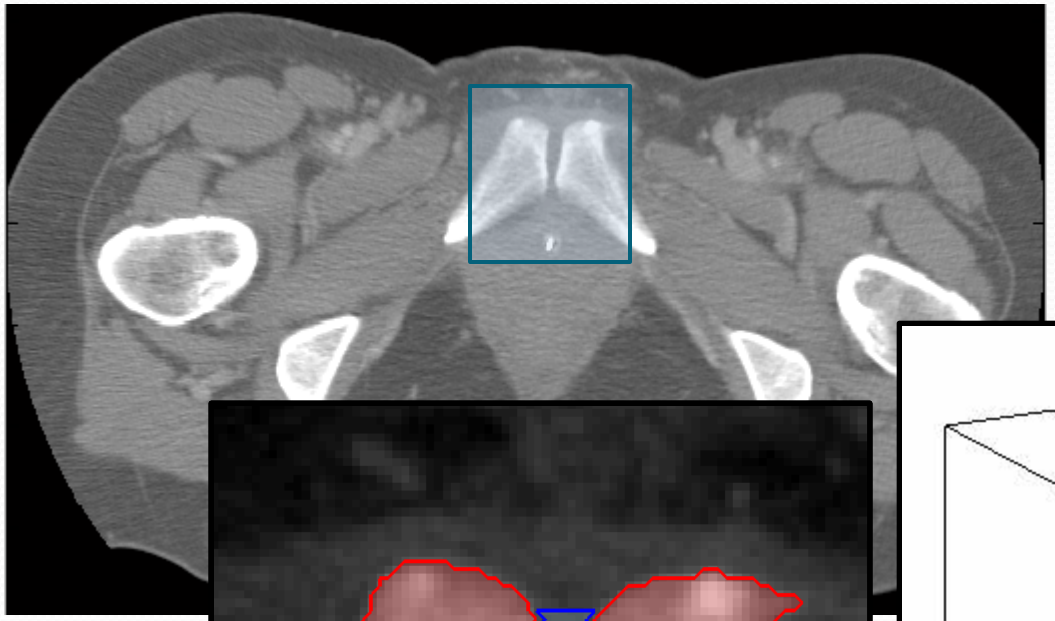
Anatomic Factors Affecting Pelvic Injury: Pubic Rami Cross Section

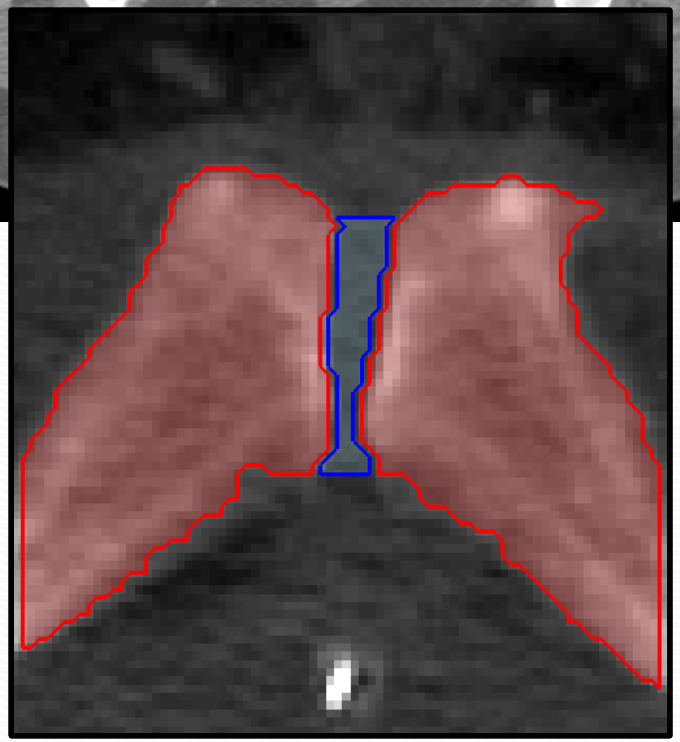




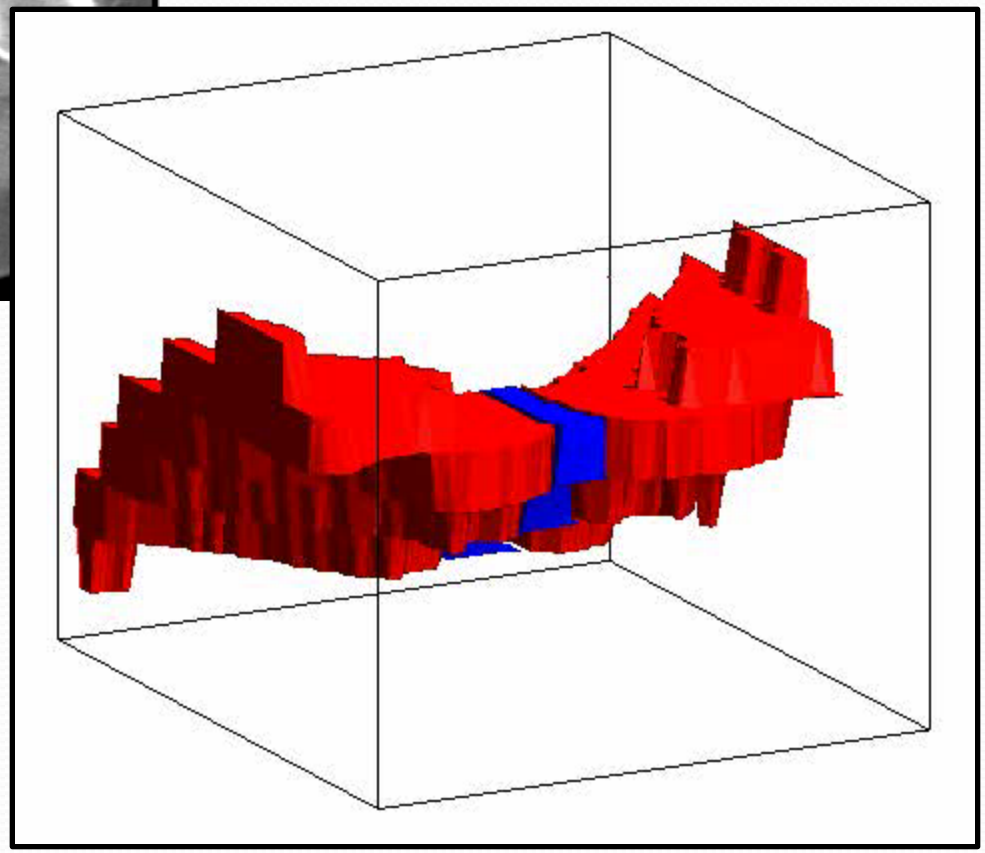
Males have a larger pubic ramus cross section (95% confidence, $P<0.001$)
Increased strength in the pubic rami for males
Same trends observed outside the CIREN population

Pubic Symphysis measurement



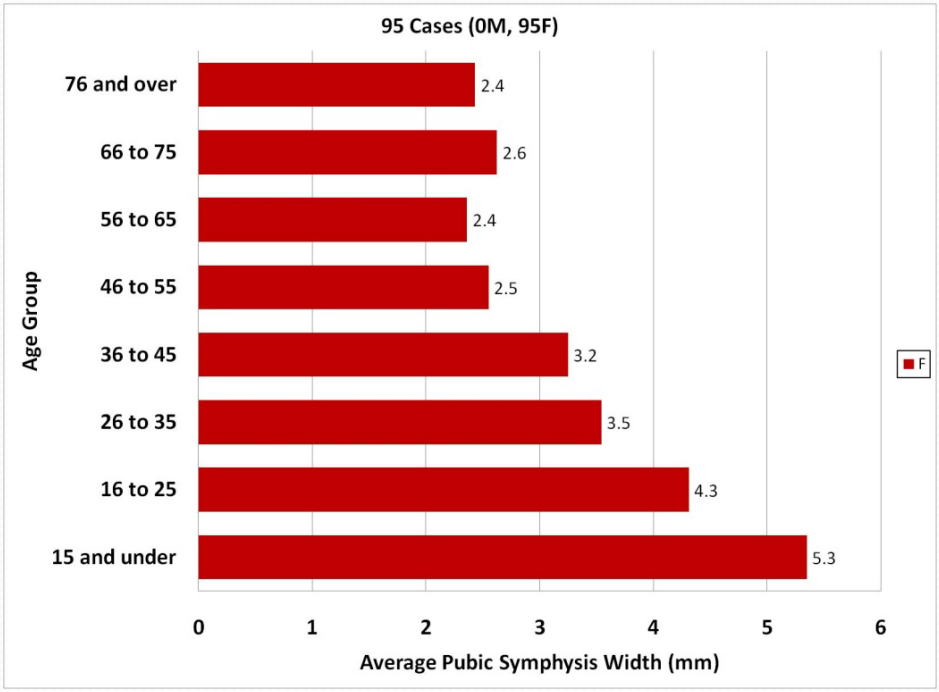


- Pelvis image from CT
- Zoom in on pubis
- Extract pubic bone
- Leaving pubic symphysis
- Record pubic symphysis width

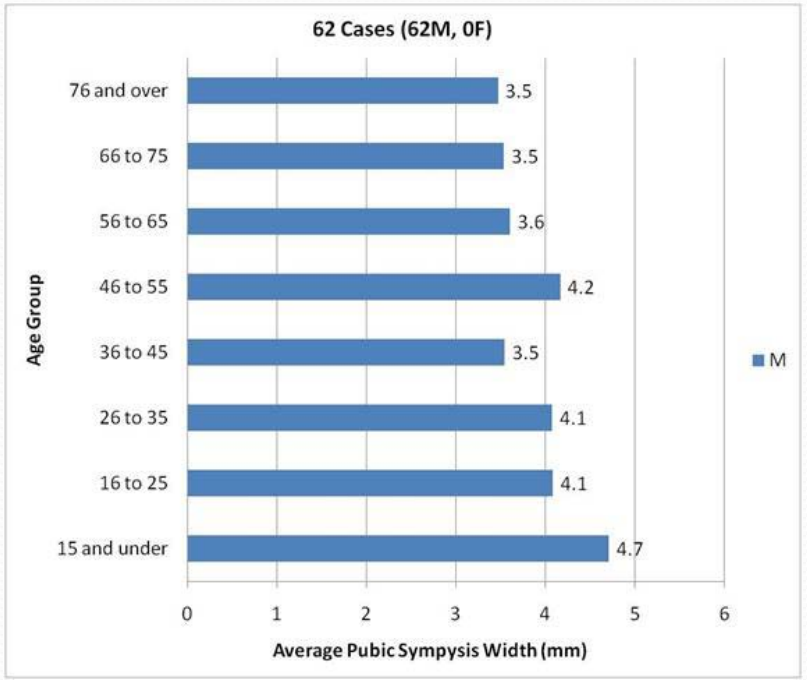


Anatomic Factors Affecting Pelvic Injury: Pubic Symphysis Width

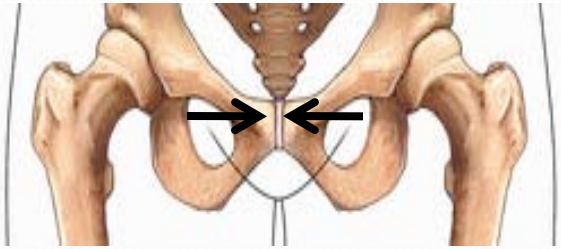
Females



Males



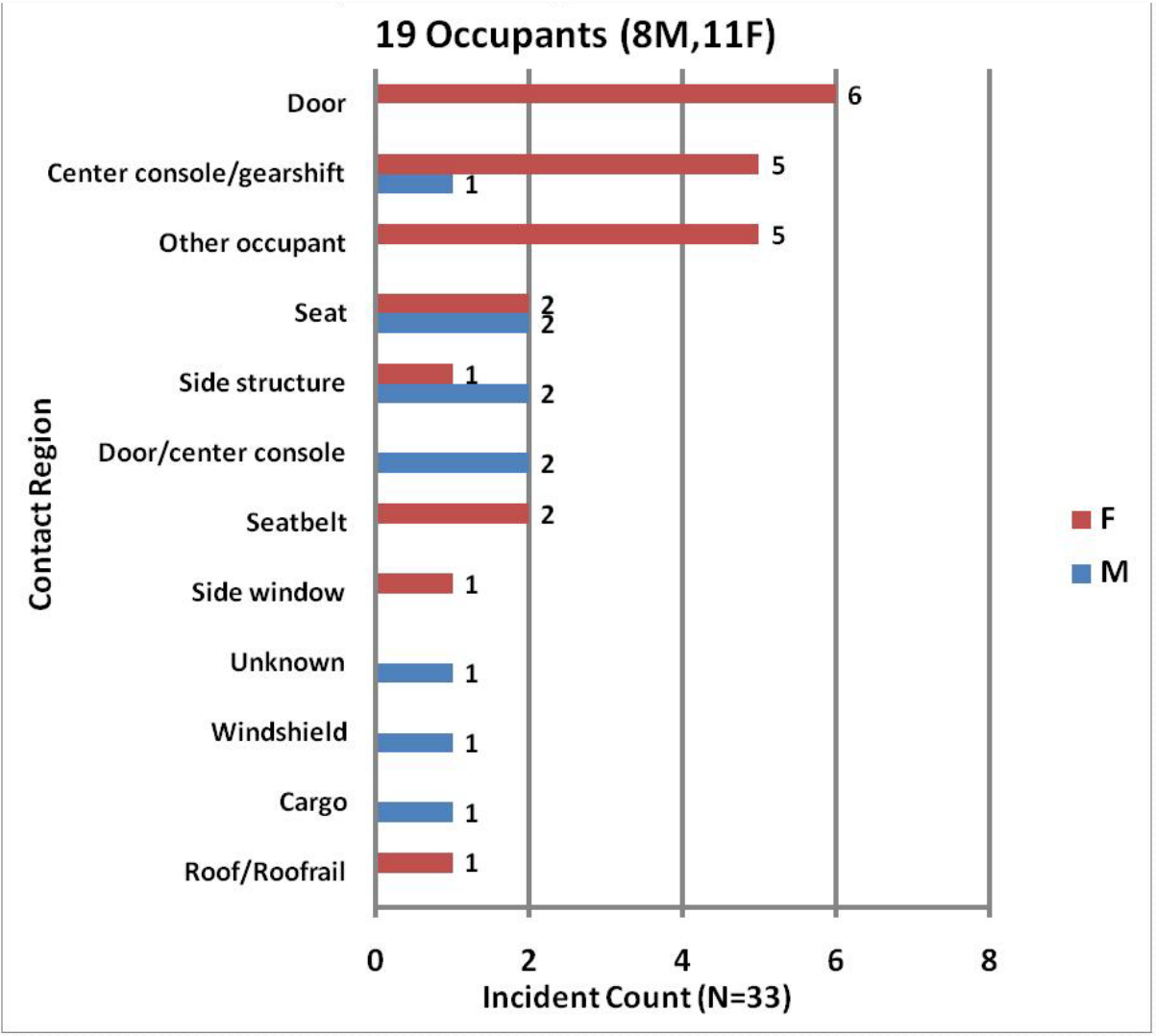
- The average width of the pubic symphysis decreases with age, particularly for women after child bearing age ($P<0.001$)
- Greater pubic symphysis width may increase the flexibility of the joint and may contribute to increased potential for fracture in younger women



Far Side Occupants

- Investigated far side occupants in crashes involving occupant compartment
  - Similar trends to near side occupants:
    - BMI
    - Injured Body Region
    - Specific Lower Extremity Injuries
  - Dissimilar
    - Contact locations
    - Average Intrusion

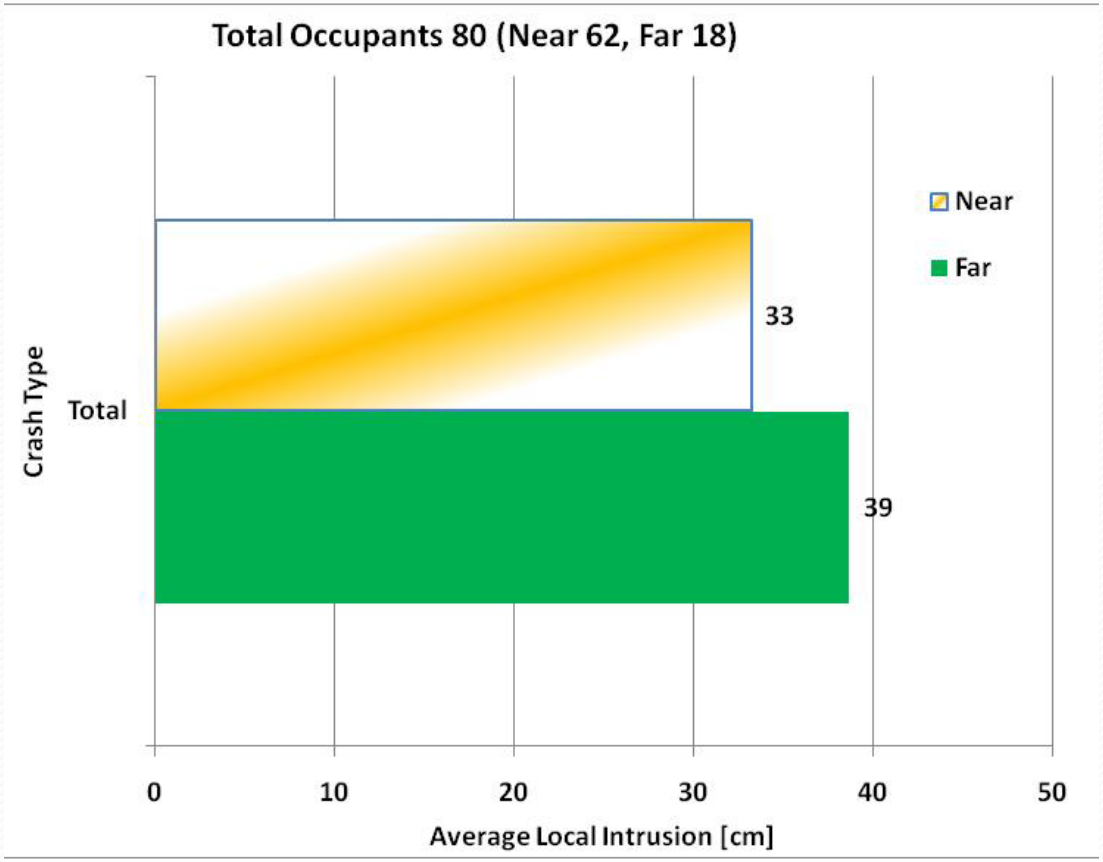
Far Side Occupant: Injury Contact Locations



- The majority of injuries were assigned to contact with:
  - struck door
  - center console/gearshift
  - other occupant

Far Side Occupant: Local Intrusion

- Typically these crashes sustained greater average intrusion than near side crashes

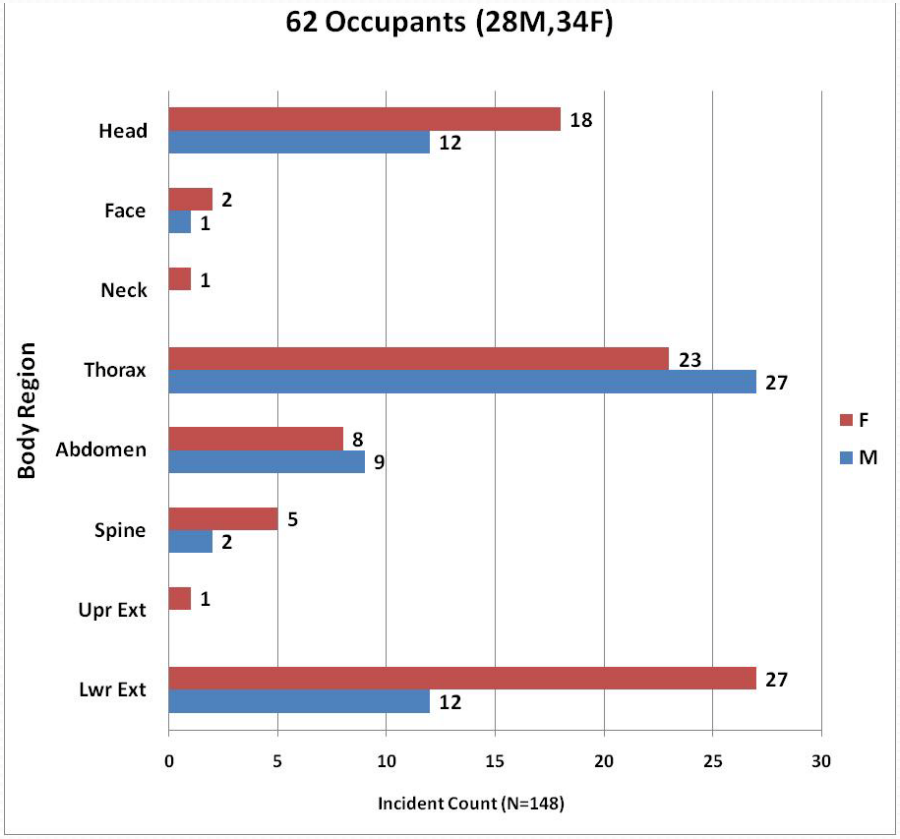


Forward of Occupant Compartment (FOC) Crashes

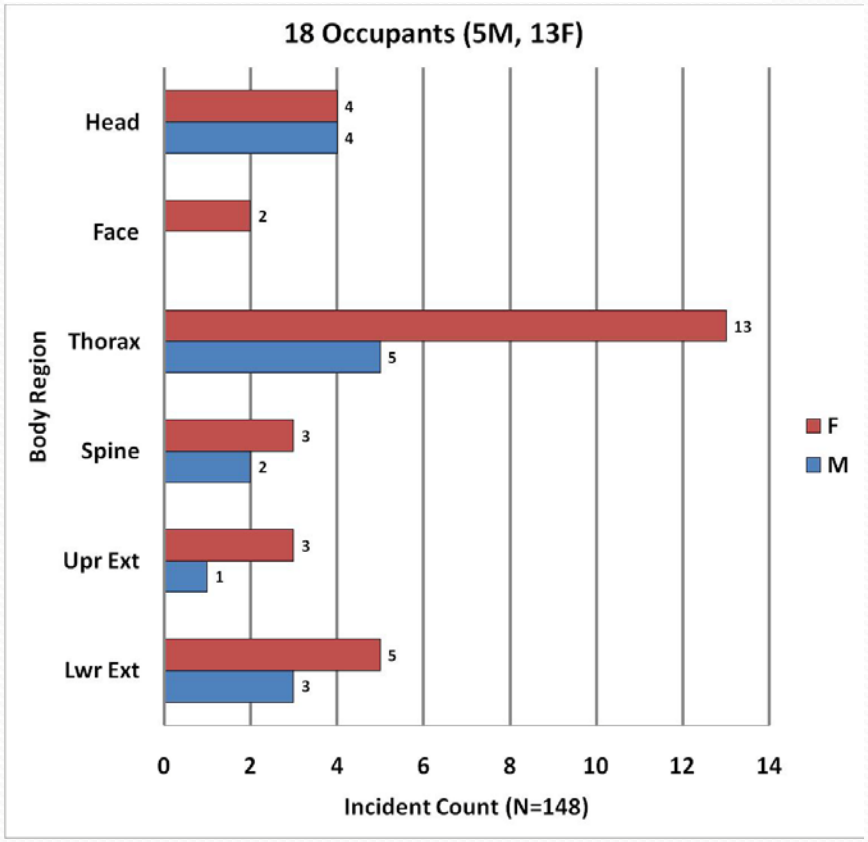
- Investigated crashes where the center of impact lies forward of the occupant compartment
  - Body regions injured
  - Contact locations
  - Gender
  - Age

Forward of Occupant Compartment Impacts - Body Region

Near-Side, Occupant-Compartment Impacts



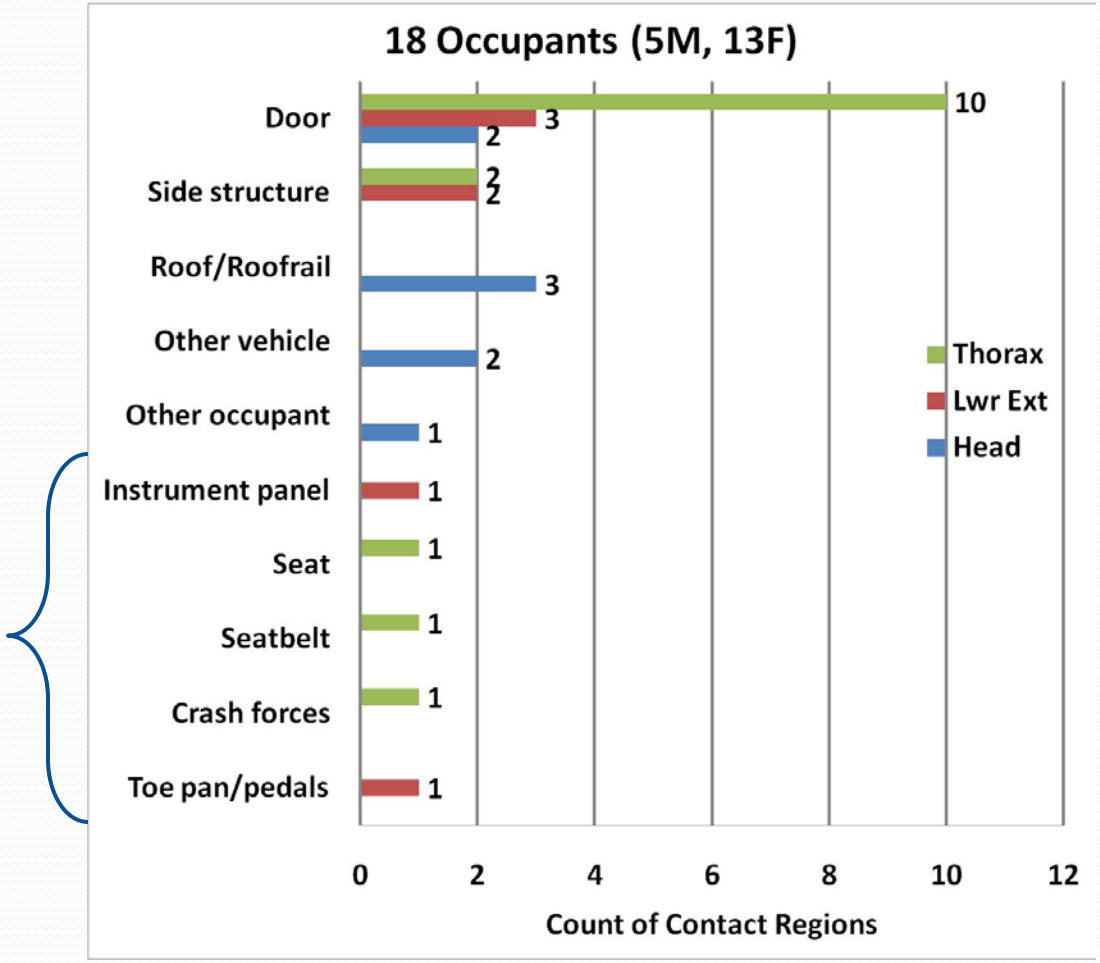
Near-Side FOC Impacts



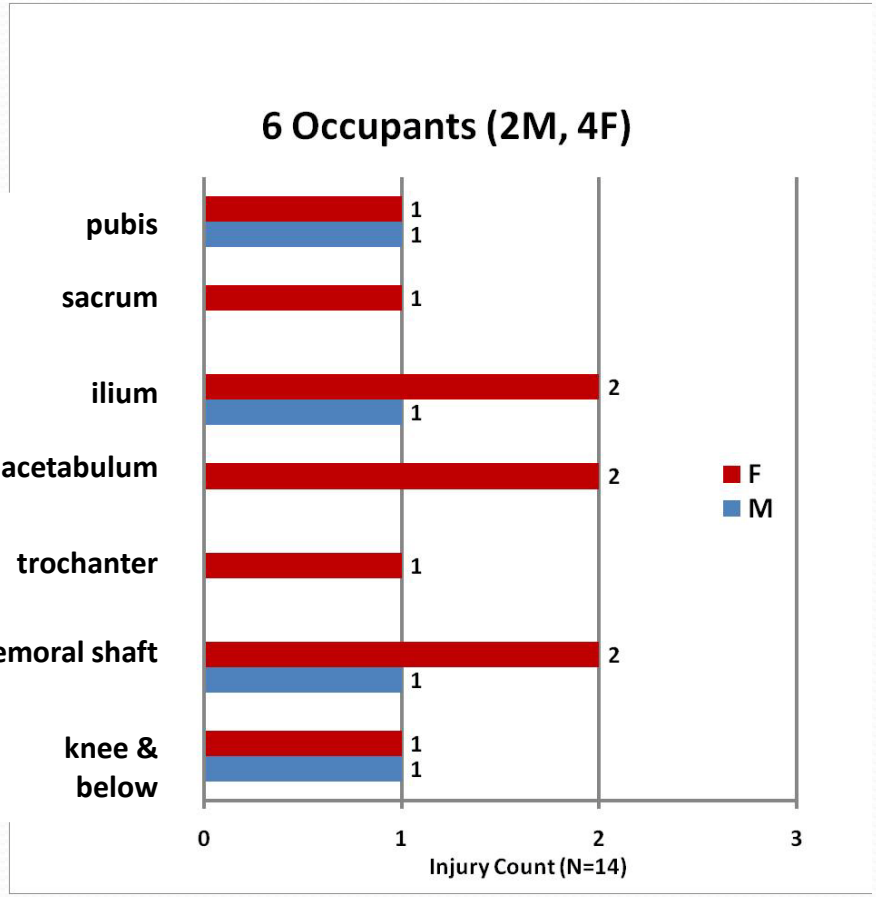
- An increased % of female thoracic injuries FOC
- Fewer lower extremity injuries

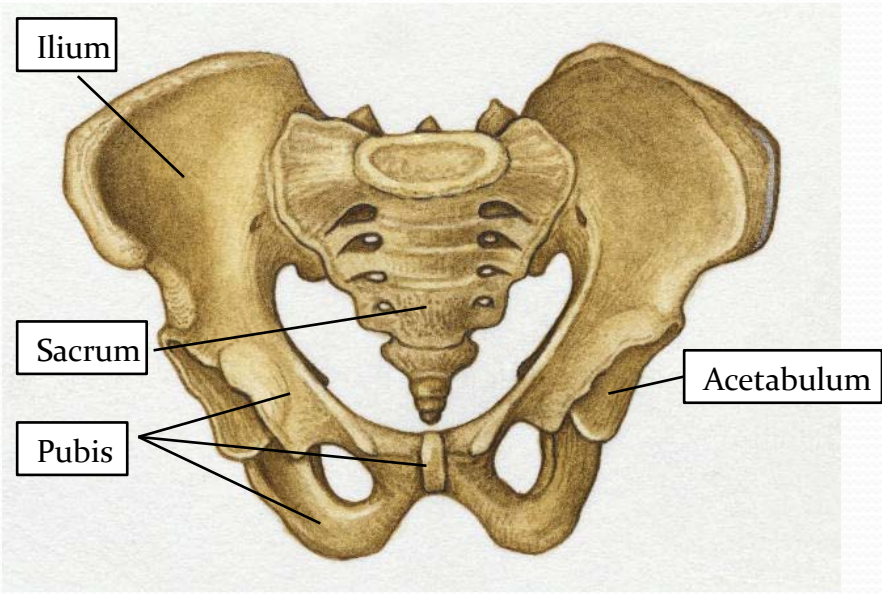
FOC - Contact Locations by Body Region

- Some contact locations suggest longitudinal component
- Frontal airbags deployed in 13/18 cases (72%)



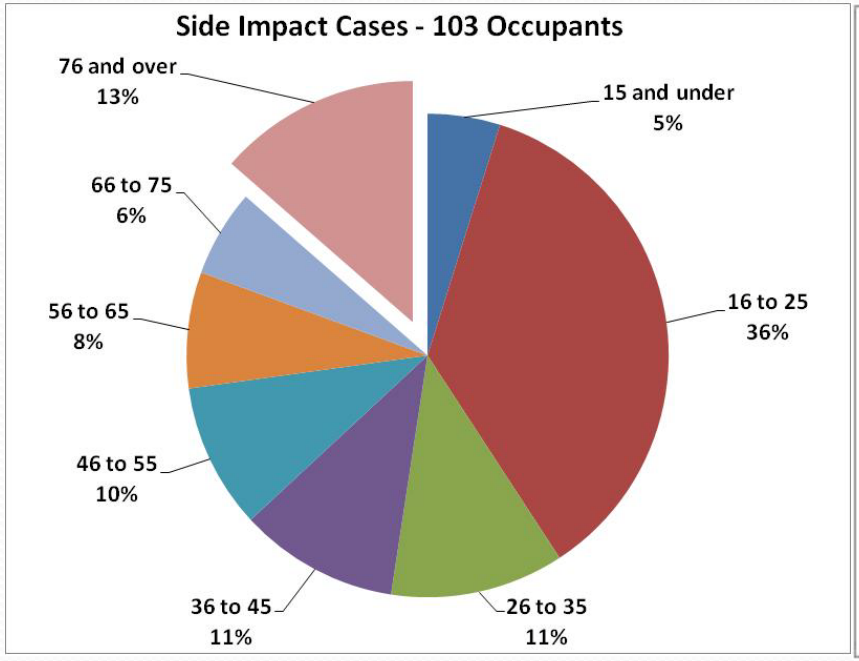
Specific Lower Extremity Injuries (AIS3+), FOC Occupant: Gender

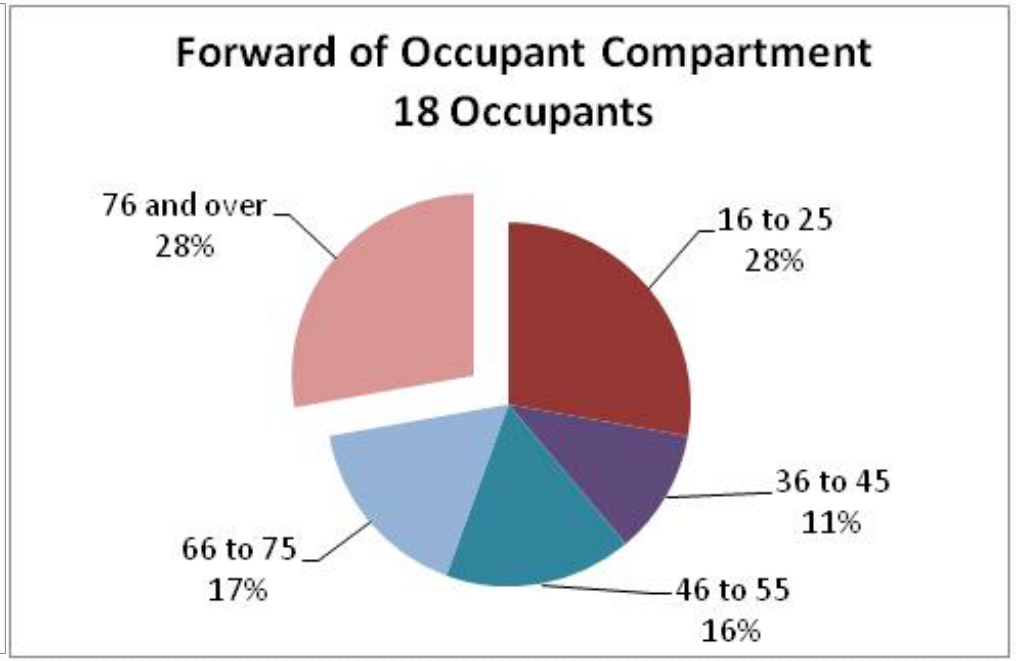




- Lower extremity injuries are no longer predominately pubis fractures
- More even injury pattern between pelvis and leg
- Injury pattern suggests combined longitudinal and lateral loading

FOC by Age Distribution





Compared to All Side Impact Cases, the FOC crashes have :

- a larger percentage of older occupants (66+)
- a lower percentage of young occupants (16-25)

Side Impact Summary

Classifying side-impact crashes (of 103 cases):

- Most had similar configurations to current industry tests (IIHS, SNCAP, & pole)
- Majority of the remaining cases involved far-side and FOC crashes
- A majority of the struck vehicles were passenger cars, with the largest category being LTV to car
- Pole, IIHS and SNCAP field events have similar average local intrusions.

Limitations:

- Database contains only severely injured occupants – not useful for injury risk/countermeasure effectiveness

Side Impact Summary

Severely injured side-impact patients when compared to patients in all types of crashes had:

- A higher proportion of females
- Similar height distributions
  – difference in gender not due to height
- A higher proportion of young adults (16 to 25 years)

Most commonly injured body regions were the head, thorax, and lower extremities

Side Impact Conclusions/Observations/Recommendations

- Anatomic differences between male and female appear to be a factor in pelvic injury patterns
- Lower injury tolerance levels for older occupants did not seem to be a major factor, except for thoracic injuries from FOC side impacts
- Re-evaluate side impact injury trends when more field cases that include side air bags are available