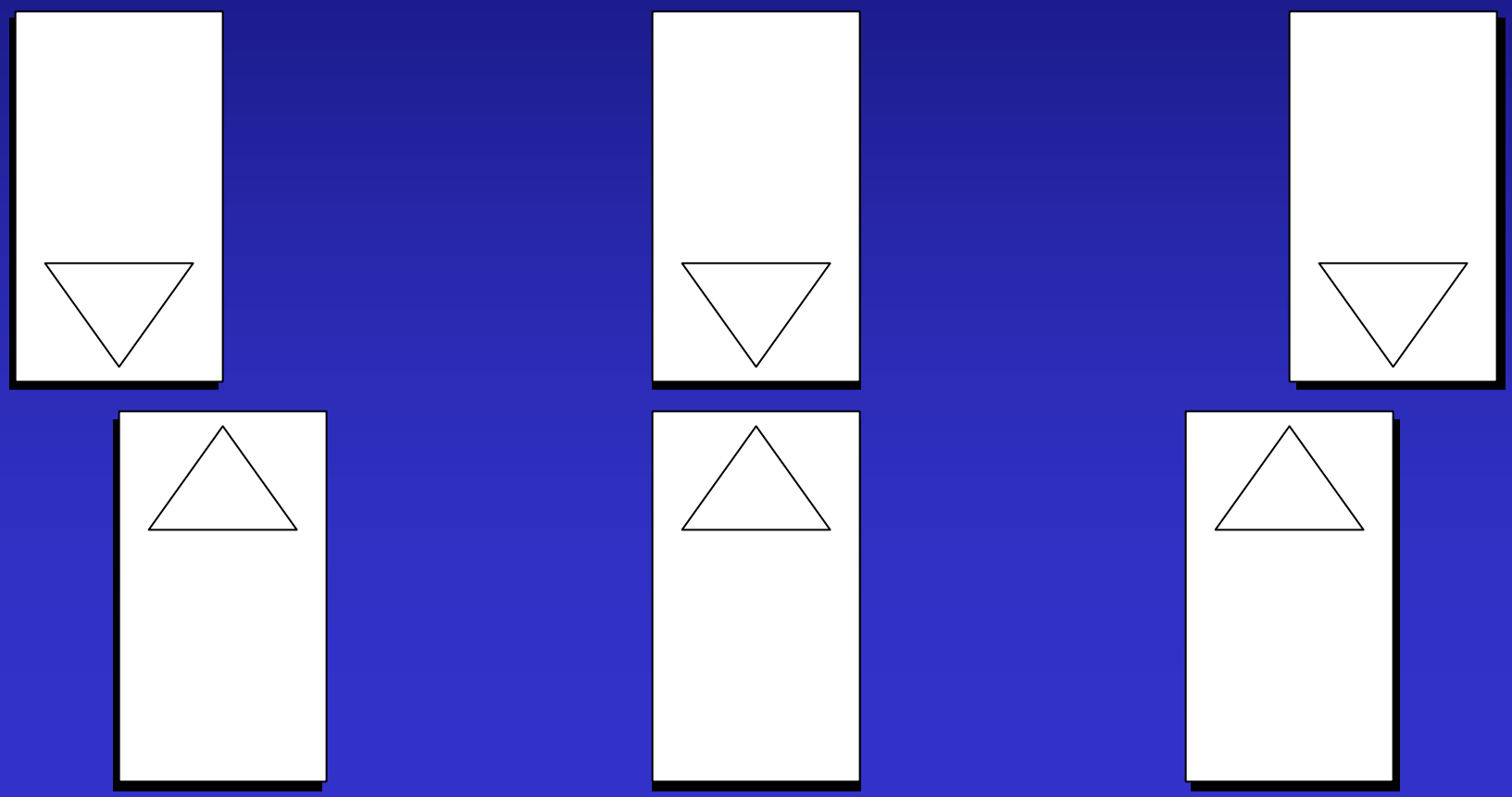
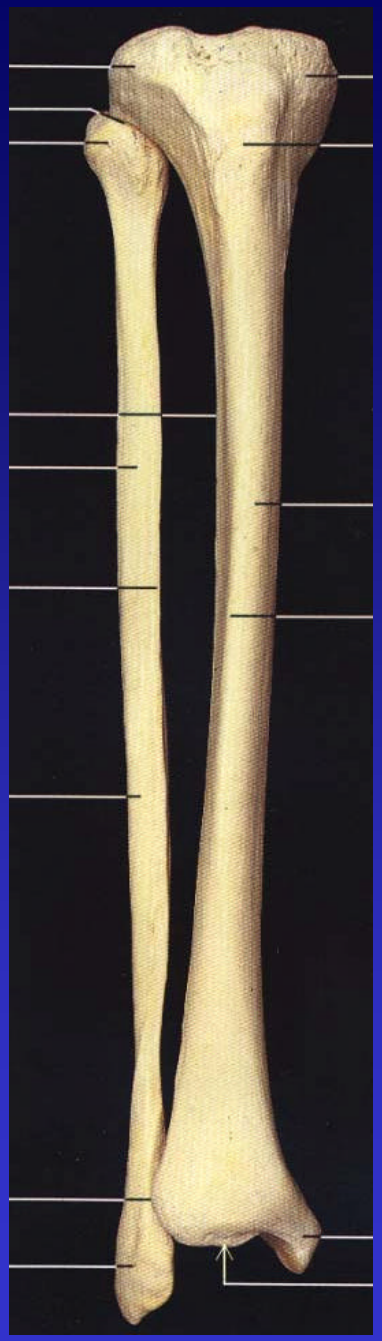
Gender Differences Related to Below Knee Fractures Following Offset MVCs

UAB CIREN Center

Definitions

Left Offset	Full Frontal	Right Offset





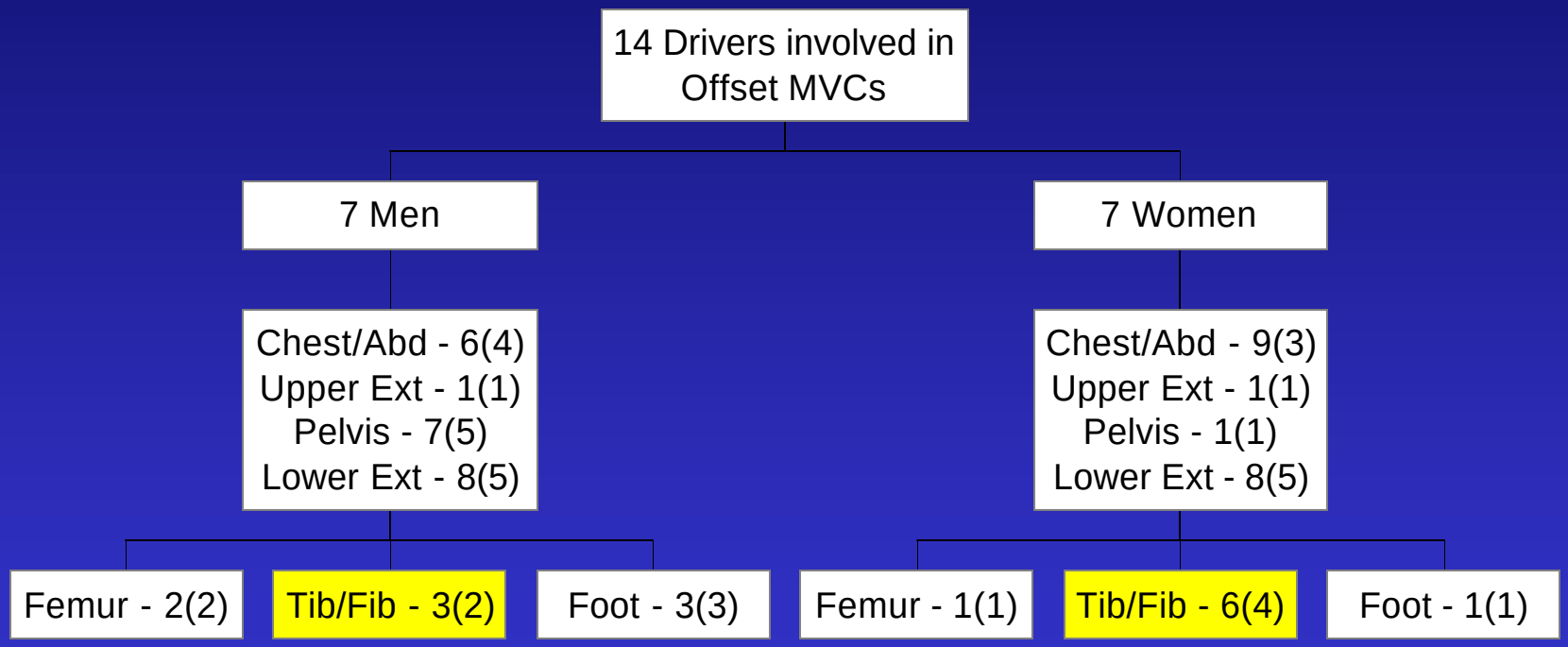
Definitions

Tibia/Fibula Fracture

NASS Definition of Tib/Fib Fx

- Tibia
  - Condyles
  - Med/Post Malleolus
  - Shaft
- Fibula
  - Head/Neck/Shaft
  - Lateral Malleolus

CIREN Cohort



Patient Demographics

Male Patients

	Age (yrs)	Mass (kg)	Height (cm)	Seat Position	Belt/Air Bag	Tib/Fib Fracture
#1	51	82	173	Forward	-/-	-
#2	24	82	165	Middle	+/N/A	-
#3	40	100	182	Rear	-/+	-
#4	48	89	180	Middle	-/+	-
#5	78	76	165	Middle	+/N/A	-
#6	35	115	185	Rear	-/+	+
#7	37	118	175	Rear	+/N/A	+

Patient Demographics

Female Patients

	Age (yrs)	Mass (kg)	Height (cm)	Seat Position	Belt/Air Bag	Tib/Fib Fracture
#1	26	58	158	Middle	+/+	-
#2	16	80	160	Middle	+/N/A	-
#3	24	76	170	Forward	-/+	-
#4	39	91	168	Forward	+/+	+
#5	34	52	152	Forward	+/+	+
#6	20	57	168	Forward	-/+	+
#7	54	86	142	Forward	+/+	+

Patient Demographics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Age (yrs)	Mass (kg)	Height (cm)	Seat Position	Belt/Air Bag	Tib/Fib Fracture
M	35	115	185	Rear	-/+	+
M	37	118	175	Rear	+/N/A	+
F	39	91	168	Forward	+/+	+
F	34	52	152	Forward	+/+	+
F	20	57	168	Forward	-/+	+
F	54	86	142	Forward	+/+	+

Crash Characteristics

Male Patients

	Collision	Delta-V	Seat Position	Toepan Intrusion	Tib/Fib Fracture
#1	Left Offset	54 kph	Middle	18 cm	-
#2	Right Offset	115 kph	Middle	55 cm	-
#3	Right Offset	60 kph	Rear	34 cm	-
#4	Right Offset	94 kph	Middle	0 cm	-
#5	Left Offset	27 kph	Middle	31 cm	-
#6	Right Offset	48 kph	Rear	7 cm	+
#7	Left Offset	30 kph	Rear	23 cm	+

Crash Characteristics

Female Patients

	Collision	Delta-V	Seat Position	Toepan Intrusion	Tib/Fib Fracture
#1	Right Offset	73 kph	Middle	19 cm	-
#2	Right Offset	28 kph	Middle	11 cm	-
#3	Left Offset	48 kph	Forward	15 cm	-
#4	Left Offset	19 kph	Forward	5 cm	+
#5	Left Offset	55 kph	Forward	52 cm	+
#6	Left Offset	56 kph	Forward	13 cm	+
#7	Left Offset	29 kph	Forward	0 cm	+

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

Case Photographs

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
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F	Left Offset	19 kph	Forward	5 cm
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Case Photographs

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

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Case Photographs

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	**Left Offset**	**56 kph**	**Forward**	**13 cm**
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

Case Photographs

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
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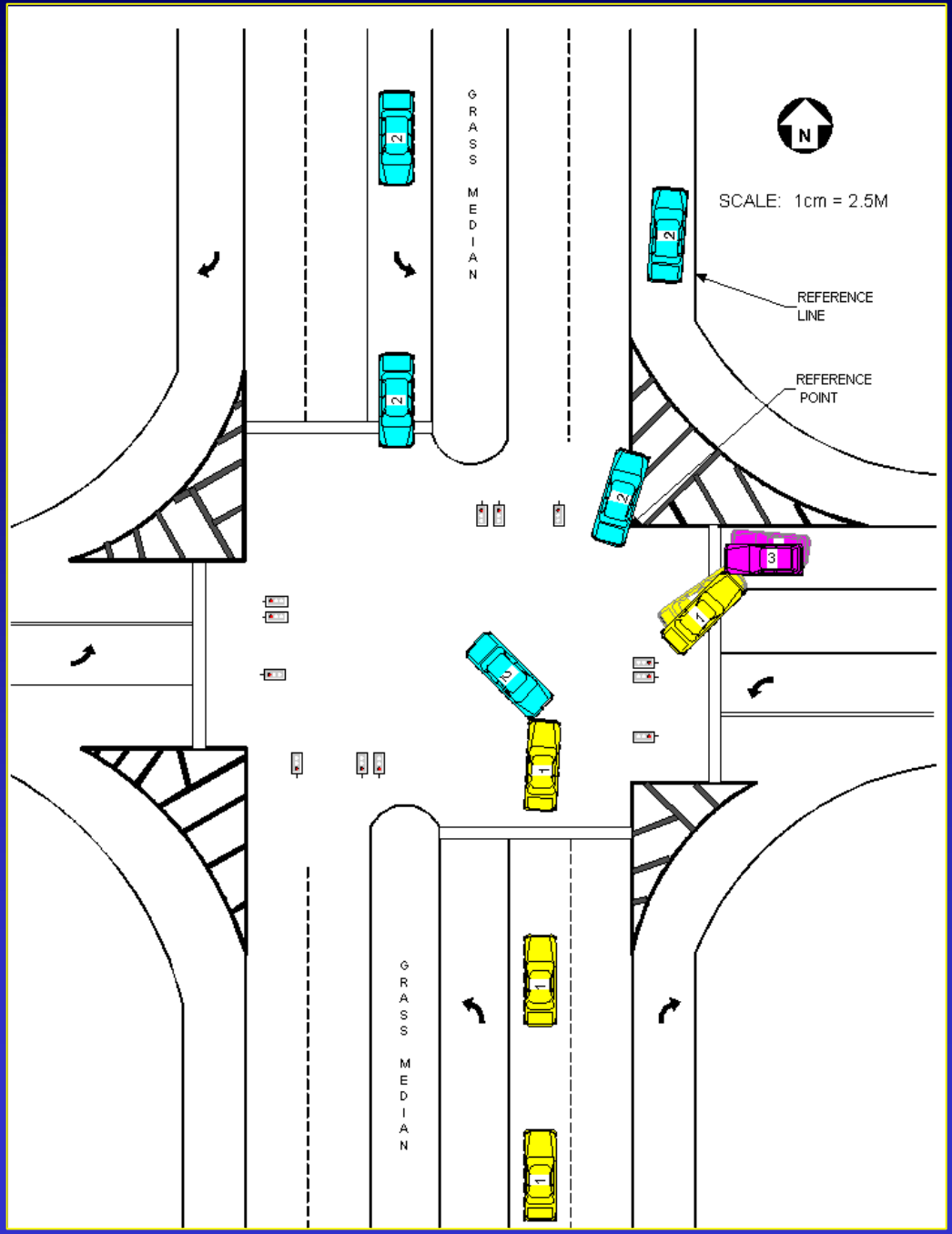
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

- V1 1995 Chevrolet Monte Carlo
- V2 1998 Cadillac DeVille
- V3 1995 Eagle Summit
- 72 kmph / 45 mph
- Lap & Shoulder Belt
- Airbag Deployed



PDOF = -30° CDC = 11FYEW2 ΔV = 19 kmph / 12 mph

VOL = 36% Left Curb weight = 1500 kg / 3307 lb

Toepan intrusion =
5 cm / 2 in
Longitudinal
PUSH TO
RELEASE

ANTI-LOCK BRAKE SYSTEM

LOCK BRAKE SYSTEM

Right Tibia/Fibula Fracture

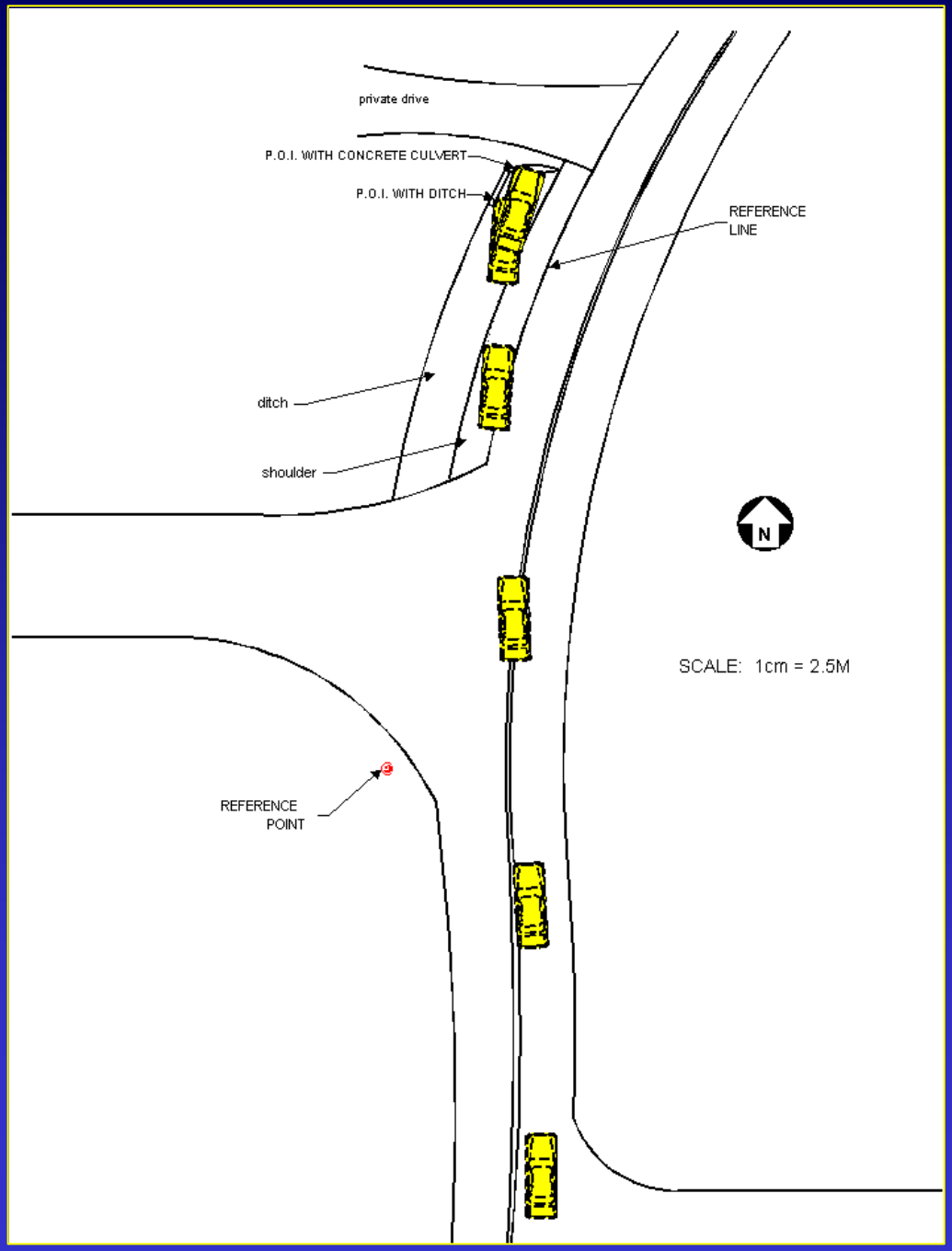
Open Right Tibia/Fibula Fracture

Crash Characteristics

Comparison of Patients with Tibia/Fibula Fractures

Gender	Collision	Delta-V	Seat Position	Toepan Intrusion
M	Right Offset	48 kph	Rear	7 cm
M	Left Offset	30 kph	Rear	23 cm
F	Left Offset	55 kph	Forward	52 cm
F	Left Offset	56 kph	Forward	13 cm
F	Left Offset	19 kph	Forward	5 cm
F	Left Offset	29 kph	Forward	0 cm

- 1997 Pontiac Grand Am
- Struck a ditch / culvert
- 64 kmph / 40 mph
- Lap & Shoulder Belt
- Airbag deployed



PDOF = 0° CDC = 12FYEW2 ΔV = 29 kmph / 18 mph

VOL = 47% Left Curb weight = 1413 kg / 3115 lb

No Intrusion

ANTI-LOCK BRAKE

ANTI-LOCK BRAKES

Right Tibia/Fibula Fracture

Right Tibia/Fibula Fracture

Overall Comparison of Offset Frontal Collisions with Tib/Fib Fractures

Gender	Height	Seat Position	Belt/Air Bag	Delta-V	Toepan Intrusion
M	185	Rear	-/+	48 kph	7 cm
M	175	Rear	+/N/A	30 kph	23 cm
F	152	Forward	+/+	55 kph	52 cm
F	168	Forward	-/+	56 kph	13 cm
F	168	Forward	+/+	19 kph	5 cm
F	142	Forward	+/+	29 kph	0 cm

Gender Differences in the Incidence of Tibia-Fibula Fractures in Offset Frontal Collisions

Center for Injury Sciences
University of Alabama at Birmingham

Hypotheses

Females have higher rates of tibia-fibula fractures in offset frontal collisions.

This association can be explained by driver height and/or seating position.

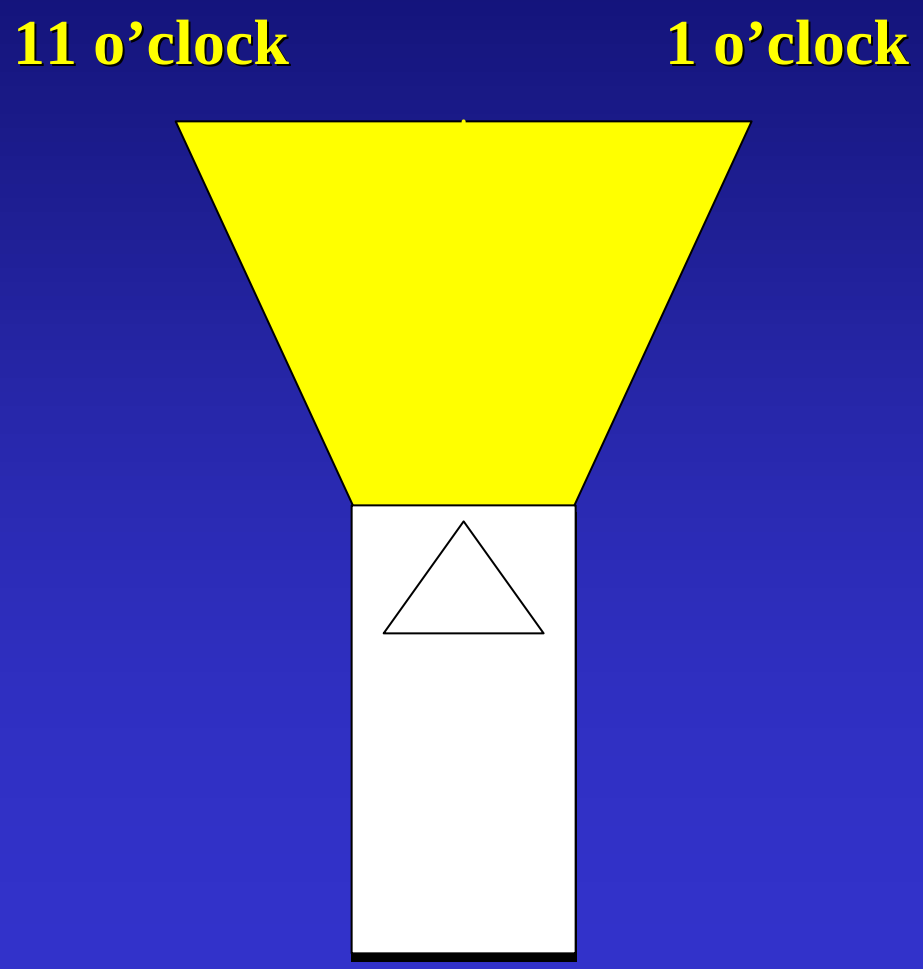
Methods – Data Source

National Automotive Sampling System (NASS) data, 1995-1999

Methods – Study Population

- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles

Methods – Study Population

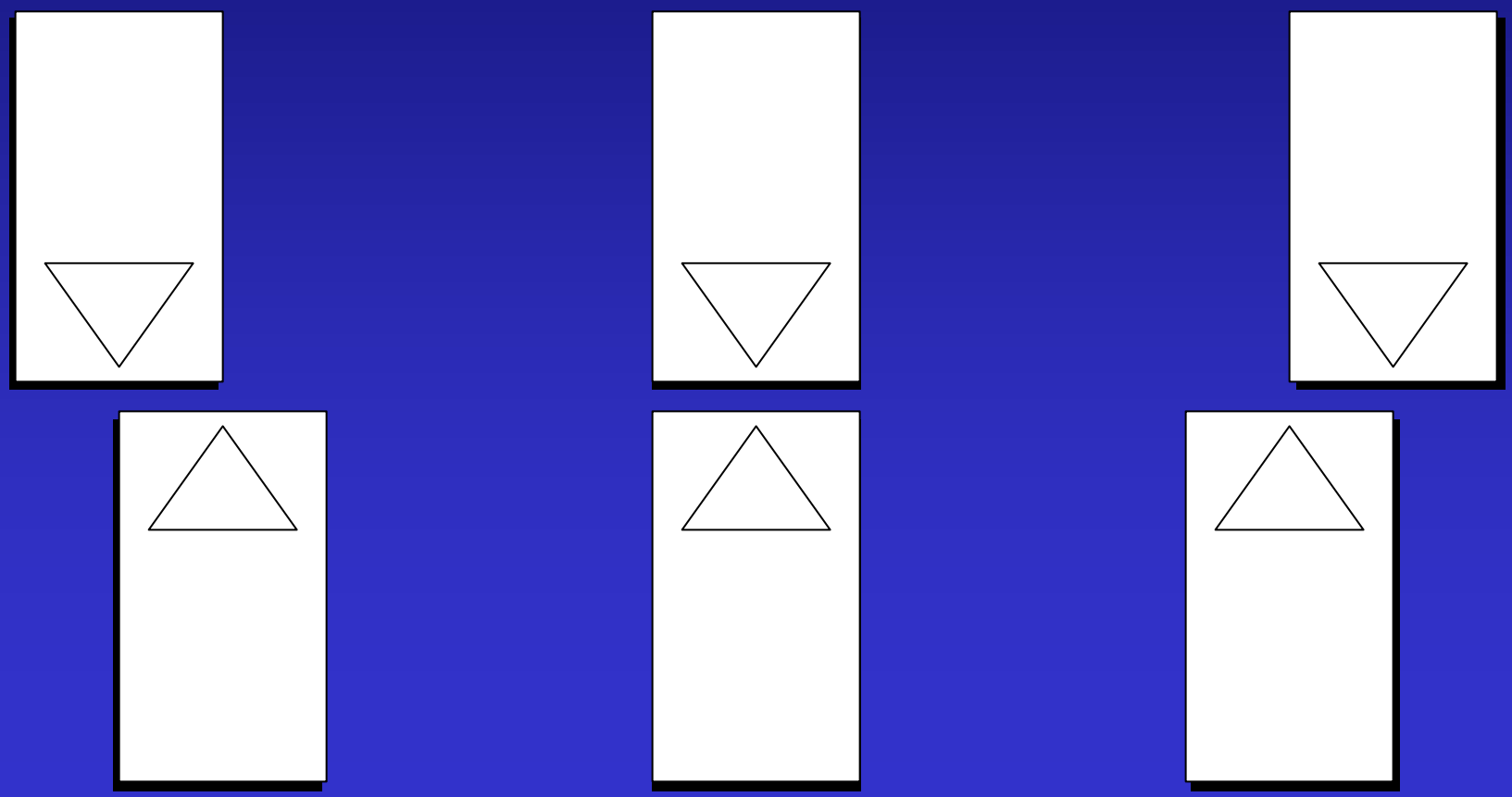


Methods – Study Population

- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles
- Within each case, vehicles were classified as full frontal, left offset frontal, right offset frontal using Specific Horizontal Location information

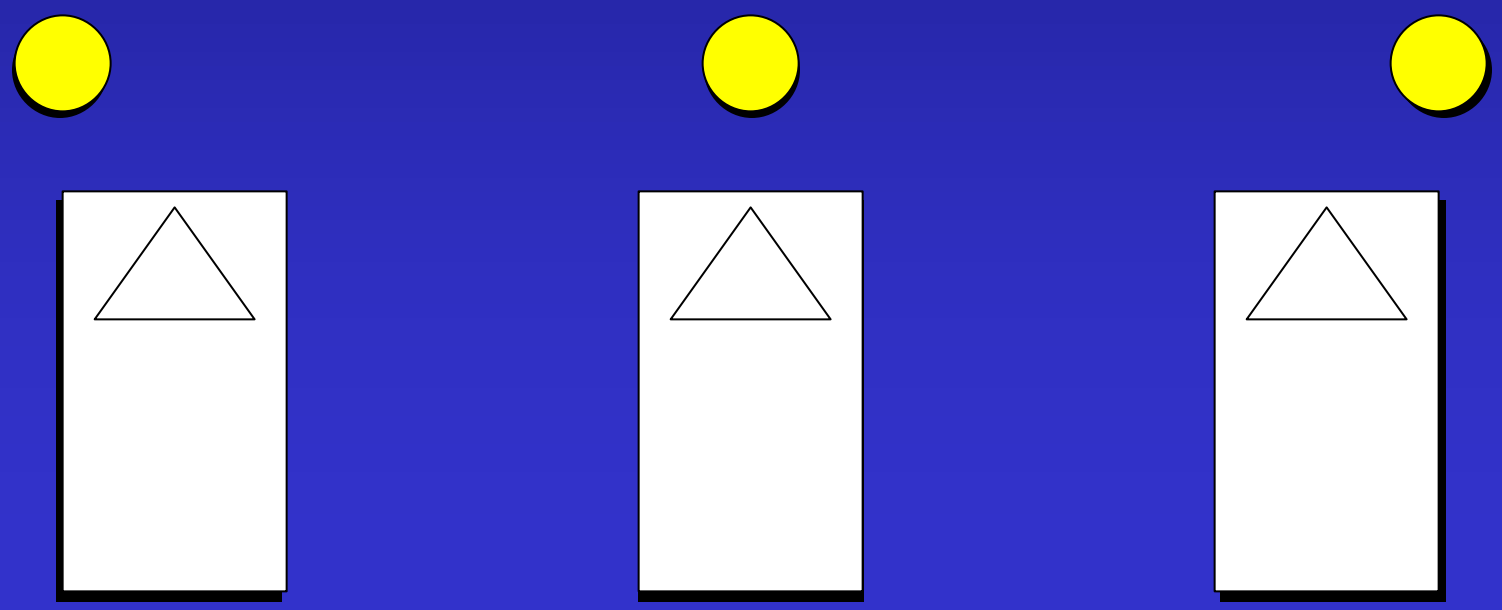
Methods – Study Population

Left Offset | **Full Frontal** | **Right Offset**



Methods – Study Population

Left Offset **Full Frontal** **Right Offset**



Methods – Study Population

- Selected cases wherein initial event was frontal collision (o'clock direction of force) and partial/complete inspection of vehicles
- Within each case, vehicles were classified as full frontal, left offset frontal, right offset frontal using Specific Horizontal Location information
- Only drivers were included in the present analysis

Methods - Definitions

Primary Outcome of Interest
Tibia/Fibula (TF) Fracture

- ***Tibia Fracture***
  - AIS 90 codes 853404.2 – 853422.3
- ***Fibula Fracture***
  - AIS 90 codes 851605.2 – 851612.2

Methods - Definitions

Selected Measures of Interest

- *Occupant Characteristics*
  - Age, gender, height, restraint use, seating position
- *Vehicle Characteristics*
  - Weight, intrusion
- *Collision Characteristics*
  - Change in velocity

Methods - Analysis

Analyses conducted using weighted data

- Calculate and compare TF fracture rates among males and females in offset collisions
- Stratify gender-specific TF rates by occupant, vehicle, and collisions characteristics
- Odds ratios (ORs) and 95% confidence intervals (CIs) calculated using SUDAAN to account for multistage sampling in NASS

Results

Final Study Population Following Exclusions

	Number	Percent
Left Offset	608,035	32.1
Full Frontal	713,278	37.7
Right Offset	570,439	30.2

Results

Lower Extremity Injury Rates
ALL Frontal Collisions

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Pelvic Fracture	0.92	0.96	1.05
Femur Fracture	1.33	1.47	1.10
Tib./Fib. Fracture	2.55	2.05	0.80

Results

Gender Odds Ratios
Males vs. Females

	Left Offset	Full Frontal	Right Offset
Pelvic	1.96	0.68	0.72
Femur	1.23	0.96	1.62
Tib./Fib.	0.72	1.20	0.37

Results

Gender Odds Ratios
Males vs. Females

	Left Offset	Full Frontal	Right Offset
Pelvic	1.96	0.68	0.72
Femur	1.23	0.96	1.62
Tib./Fib.	0.72	1.20	0.37

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

Age	Female	Male	Odds Ratio
	Rate per 100 Occupants		
<30	2.24	1.26	0.56
30-39	2.63	1.27	0.48
40-49	3.21	2.34	0.73
50-59	2.30	0.62	0.27
60-69	4.88	1.25	0.25
³ 70	2.57	4.15	1.64

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
Delta – V	Rate per 100 Occupants		
01-16	0.00	0.00	-
17-23	1.72	0.16	0.09
24-33	1.79	0.60	0.33
³ 34	16.99	6.29	0.33

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Small	2.62	1.98	0.75
Mid-Size	4.69	1.77	0.37
Large	0.90	1.07	1.19

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Unrestrained	4.86	2.44	0.49
Restrained	1.54	0.76	0.49

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Height < 5’5”	1.86	0.89	0.48
Height ³ 5’5”	2.32	1.67	0.71
Unknown	5.43	0.67	0.12

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
	Rate per 100 Occupants		
Seat Forward	2.63	0.59	0.22
Seat Middle/Back	2.35	1.54	0.65

Results

Tib./Fib. Fracture Rates
Offset Frontal Collisions

	Female	Male	Odds Ratio
Intrusion*	Rate per 100 Occupants		
Lateral <8 cm.	2.26	1.27	0.56
Lateral ³ 8 cm.	12.67	7.16	0.53
Frontal <8 cm.	1.48	0.38	0.26
Frontal ³ 8 cm.	16.82	10.34	0.57

* Driver's seating position.

Results

Intrusion Characteristics Among Occupants with Tib./Fib. Fractures

	Female	Male
Intrusion*	**Percent**	**Percent**
Lateral <8 cm.	90.6	86.3
Lateral ³ 8 cm.	9.4	13.7
Frontal <8 cm.	56.3	24.0
Frontal ³ 8 cm.	43.7	76.0

* Driver's seating position.

Results

Aspect of Tib./Fib. Fractures

	Left Offset		Right Offset	
	Female	Male	Female	Male
Aspect	Percent	Percent	Percent	Percent
Left	44.1	31.7	38.6	21.3
Right	53.0	54.2	59.9	69.4
Bilateral	2.9	14.1	1.5	9.3

Results

Impact Characteristics Among Occupants with Tib./Fib. Fractures

	Female	Male
Injury Source	**Percent**	**Percent**
Knee Bolster	5.3	10.8
Instrument Panel	16.3	35.2
Floor/Toe Pan	43.6	41.9
Pedals	35.9	19.3

Summary

- Females drivers have higher rates of tib./fib. fracture in offset frontal collisions
- Observed higher rates not explained by occupant, vehicle, collision characteristics
- Tib./fib. fractures in females occur at lower a delta-V and are more associated with pedal contacts

Literature Survey

Surveyed publications from the past ten years related to improving safety standards and test procedures for offset crashes as well as literature on lower extremity injuries in frontal crashes

Objective: Understand outstanding issues and compare our results to related research of others

Notable Findings

- Importance of the issue is clearly agreed upon:
  - Lower limb injuries are second only to head injuries in frequency among motor vehicle occupants
  - Lower limb injuries are a frequent cause of permanent disability and impairment; costs to society are exorbitant

Notable Findings

- Load transfer mechanism of below-knee injuries from frontal crashes are not well understood
  - Intrusion vs. deceleration
  - Effect of body rotation on below-knee injuries
  - Role of contact with pedals
  - Effectiveness of restraints
- Possible injury mechanisms have been described and compared to laboratory tests and computer modeling

Notable Findings

- Case studies indicate that there must be a lateral load component contributing to malleolar fractures
- Intrusion and lower extremity injuries increase as overlap decreases
- Toepan intrusion is not a prerequisite for tib./fib. injury

Notable Findings

- Below-knee injuries are occurring at delta-Vs less than 30 mph (48 kmph)
- Higher injury rate to driver's right lower extremities in offset crashes
- Other contributing factors postulated: leg position, foot size, contribution of knee contacts, muscle tension, maximum angle of ankle motion

Notable Findings

- Other researchers have pointed out apparent gender differences -- however, exact reasons have not been discerned
  - Size? Seat Position? Other physiological? Behavioral? External conditions such as footwear? Car attributes?
- Frontal offset crash tests indicate that lower limb forces are higher using the 5th percentile female dummy than the 50th percentile male