UNIVERSITY *of* CALIFORNIA, SAN DIEGO
MEDICAL CENTER

Brain injuries:

Does Severity, Sources, and Type of Injury vary for Distributed, Off-set, and Corner Frontal Impacts?

Presenters:

Raul Coimbra, MD, PhD, FACS, Principal Investigator

Steve Erwin, Crash Investigator

San Diego CIREN Center

March 2007 CIREN Public Meeting, Washington, DC

Objectives

- Address the magnitude of the brain injury problem
- Define Distributed, Off-set, and Corner frontal crashes
- Present examples of frontal crashes, resulting in brain injury, investigated by CIREN
- Compare brain injuries associated with specific frontal crashes using CIREN data

UNIVERSITY of CALIFORNIA, SAN DIEGO
MEDICAL CENTER

Traumatic Brain Injury

- About 1.4 million people sustain a traumatic brain injury (TBI) every year
- Almost 50,000 die annually and people with severe TBI may have long-term disability
- Motor vehicle crashes are one of the leading causes of TBI severe enough to require hospitalization
- Brain injuries are a compelling public health and motor vehicle safety problem and a treatment challenge for trauma surgeons and other medical care providers

Why Study Brain Injuries Using CIREN Data?

- Crash tests assess safety system effectiveness and crashworthiness
  - Current Head Injury Criterion (HIC) used in crash tests is based only on linear acceleration
- NHTSA : tests distributed frontal impacts
- IIHS: tests off-set frontals
- Real world experience provides information on safety system effectiveness and crashworthiness for all types of frontal impacts (including corner)

Head Injury Criterion (HIC)

- One of the “Injury Criterion Performance Limits” for testing vehicle safety
- Used to provide a quantitative measure of head injury risk during motor vehicle crash tests
- Based on average value for linear acceleration of the head’s center of gravity during a crash
  - Previously, set at “1000” for an adult mid-size male anthropomorphic dummy
  - In 2000, set at “700” for a 15 millisecond crash
  - Currently, possible changes for children (FMVSS 213)
  - Currently, possible changes using a different brain model

UNIVERSITY of CALIFORNIA, SAN DIEGO
MEDICAL CENTER

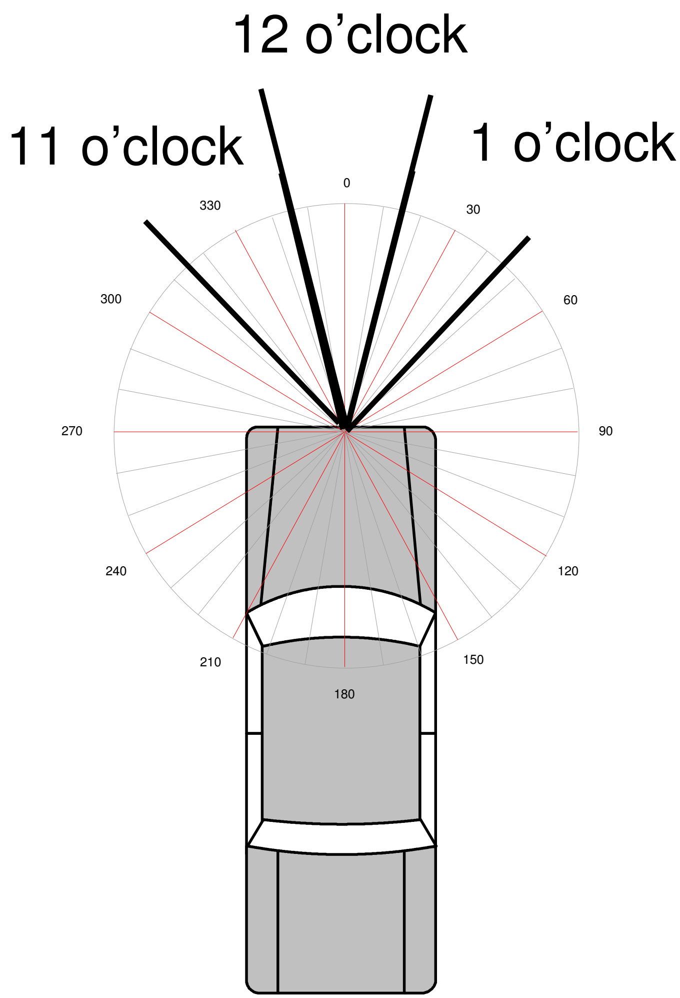
Biomechanics of Brain Injury

- Different cephalic components (brain, skull, arteries, nerves) have different physical features and anatomical structure
- Rotational forces in addition to linear acceleration may cause brain injury
- Different regional and organ mechanisms of injury are associated with different types of brain injuries
  - Tissue “strain”: Compression, shearing, tension
- Mechanism of injury may differ for different components of the brain

UNIVERSITY *of* CALIFORNIA, SAN DIEGO
MEDICAL CENTER

Frontal Impact Definitions developed for Study

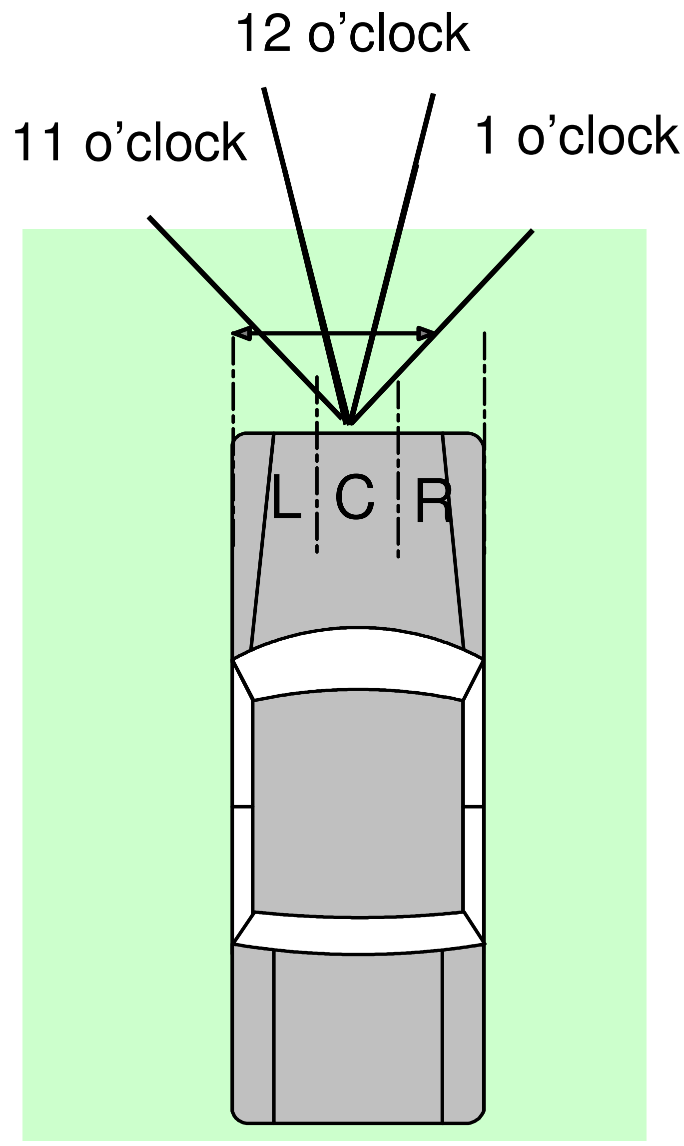
In-line frontal impact

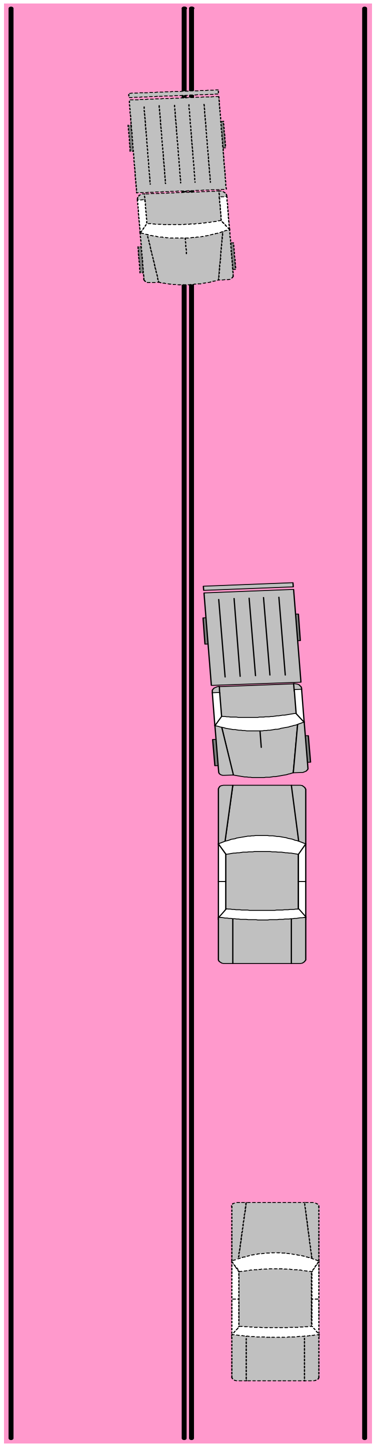


Distributed Frontal Impact

- 1st and 2nd column of CDC = 11, 12, 1
- 3rd column of CDC="F" and 4th column of CDC="D"
- 6th column of CDC= "W"

The Direct Damage is distributed across 66% (or more) of the frontal plane

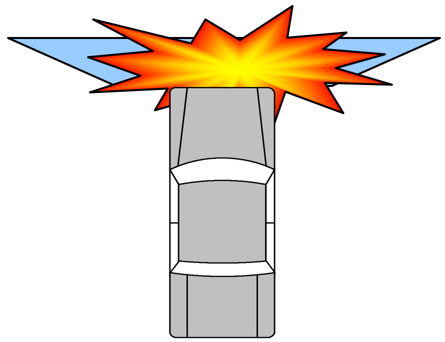


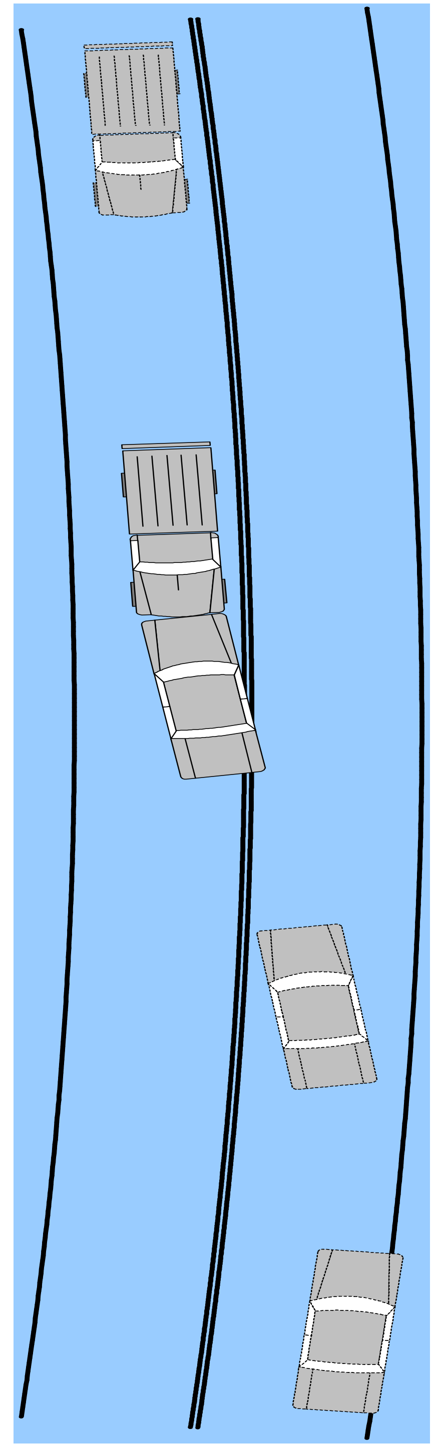


Examples of real-world Distributed Frontal crashes

'Head-on' Distributed Frontal

Comparable to the NHTSA NCAP Tests

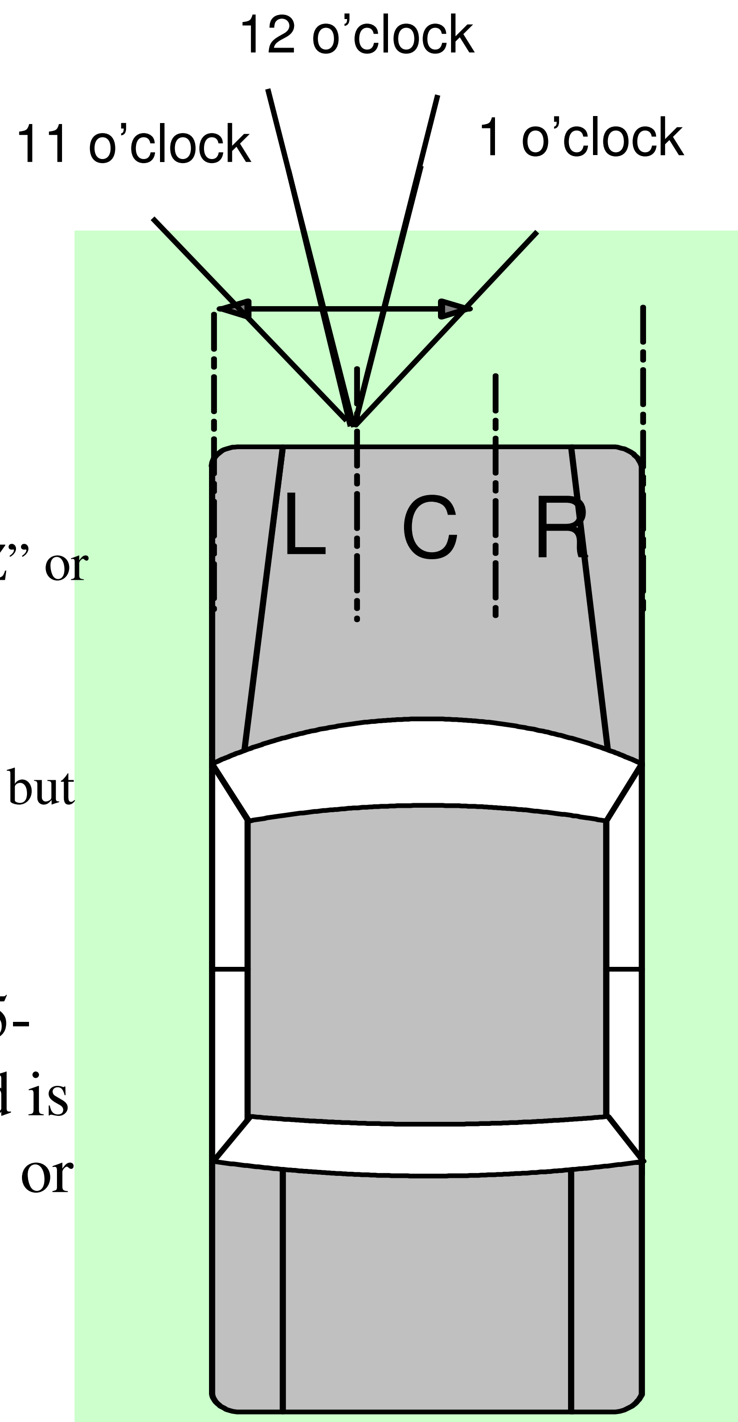


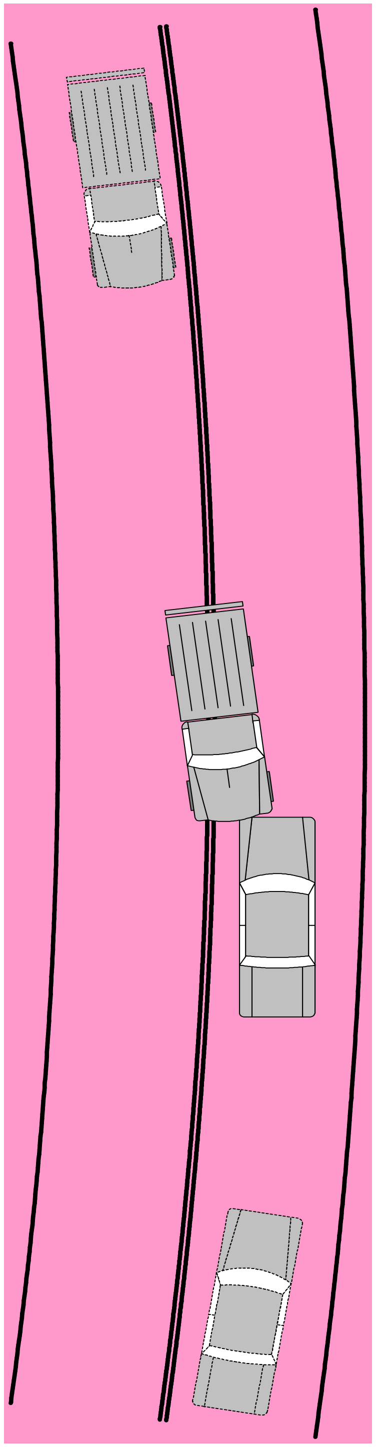


Off-set Frontal Impact

- 1st and 2nd column of CDC = 11, 12, 1
- 3rd column of CDC="F"
- 4th column of CDC="Y" or "Z" or "L" or "R"
- 5th column of CDC= anything but "W"

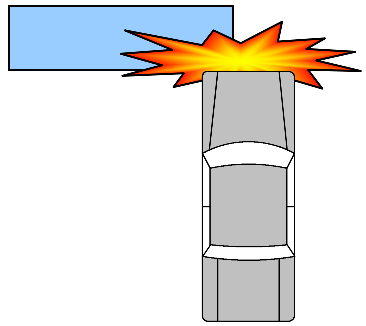
Direct Damage involves 35-65% of the Front Plane and is confined to right or left 1/3 or 2/3 of frontal plane

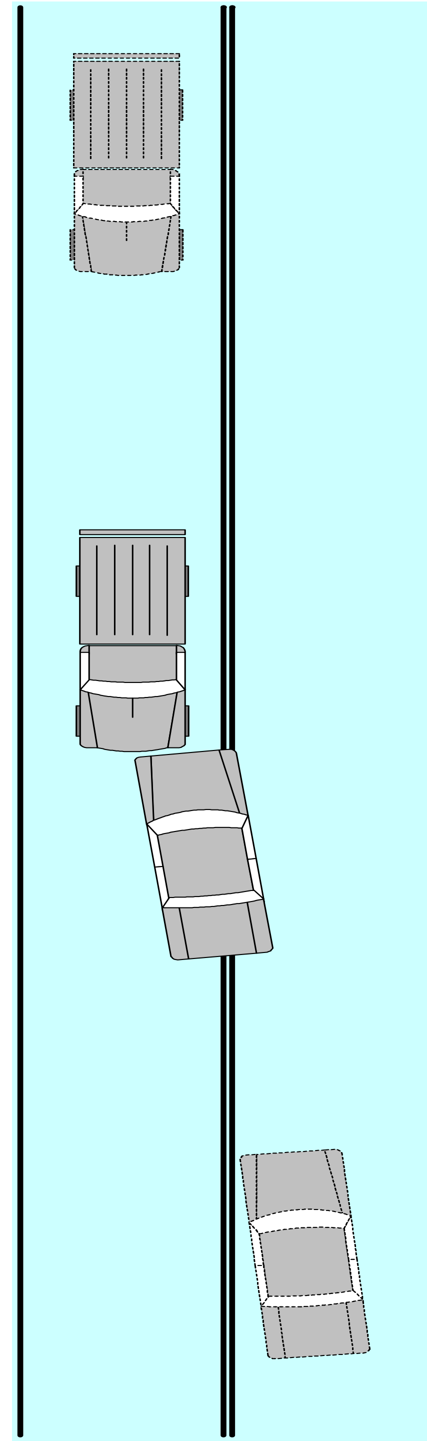


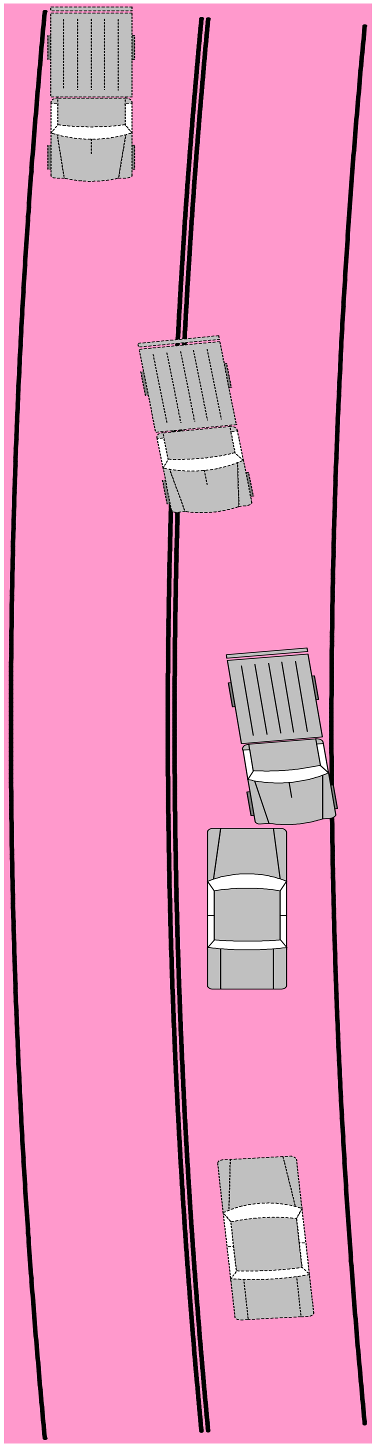


‘Head-on’ Front Left Off-set Impacts

Comparable to IIHS Crash Tests (Drivers “Left” side)

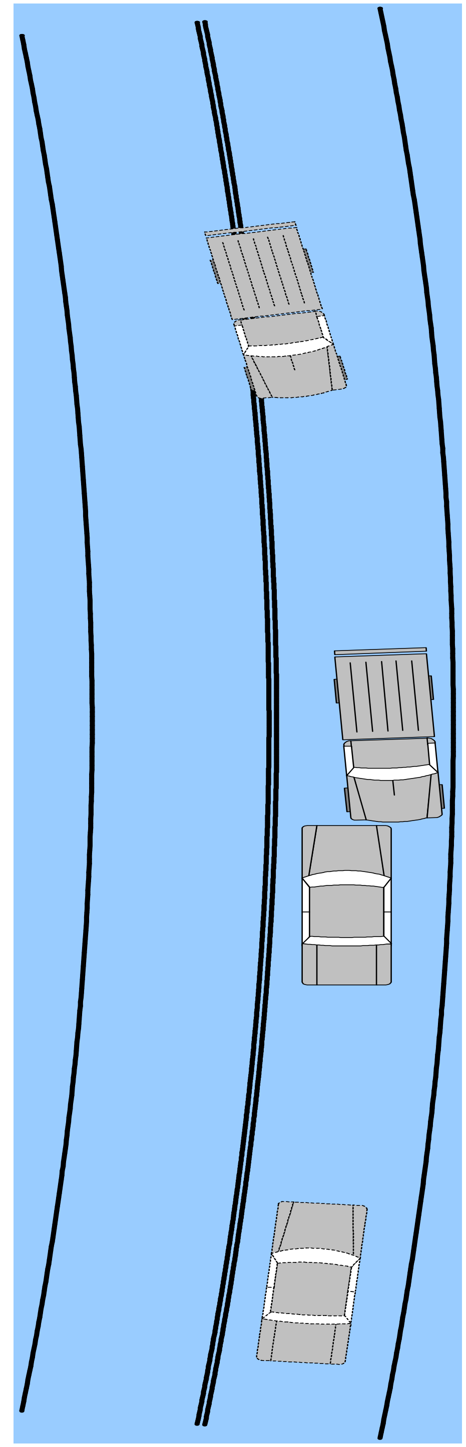






‘Head-on’ Front Right Off-set

(Passenger Side) Impacts



Corner (Extreme Off-set) Frontal Impact

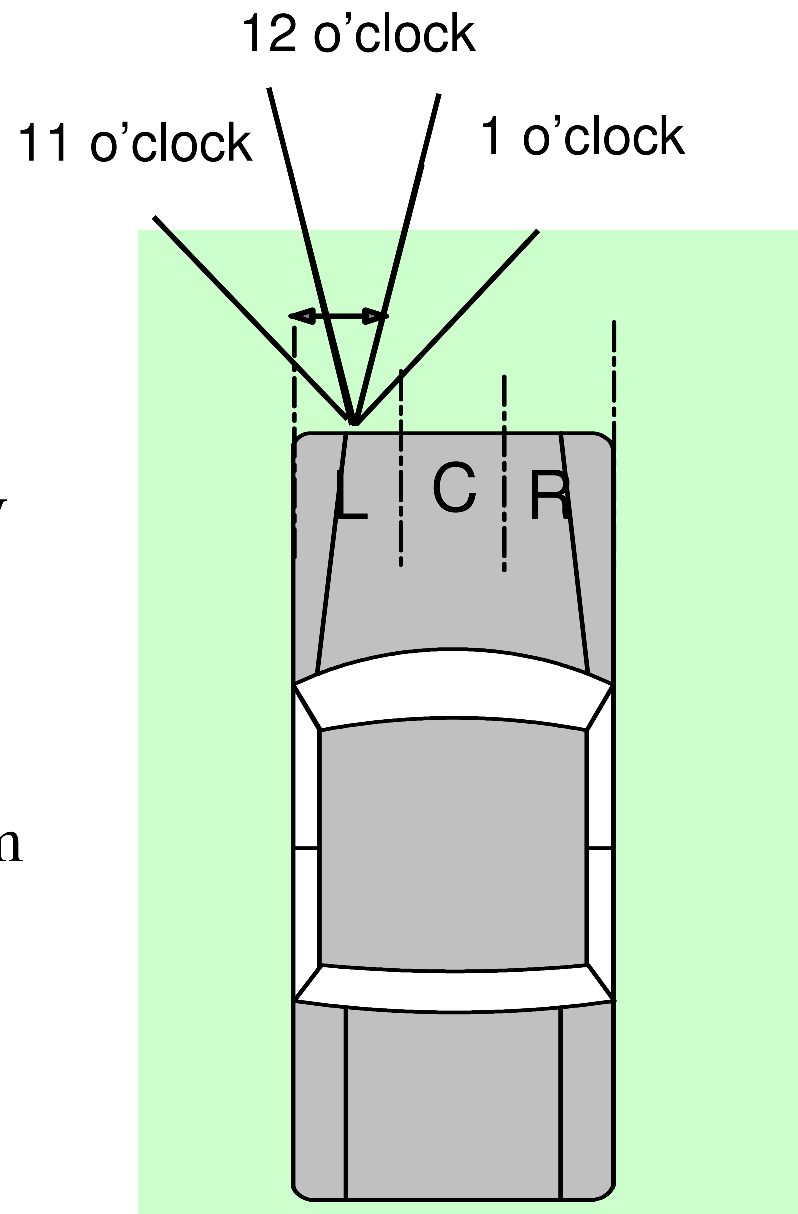
- 1st and 2nd column of CDC = 01,11,12

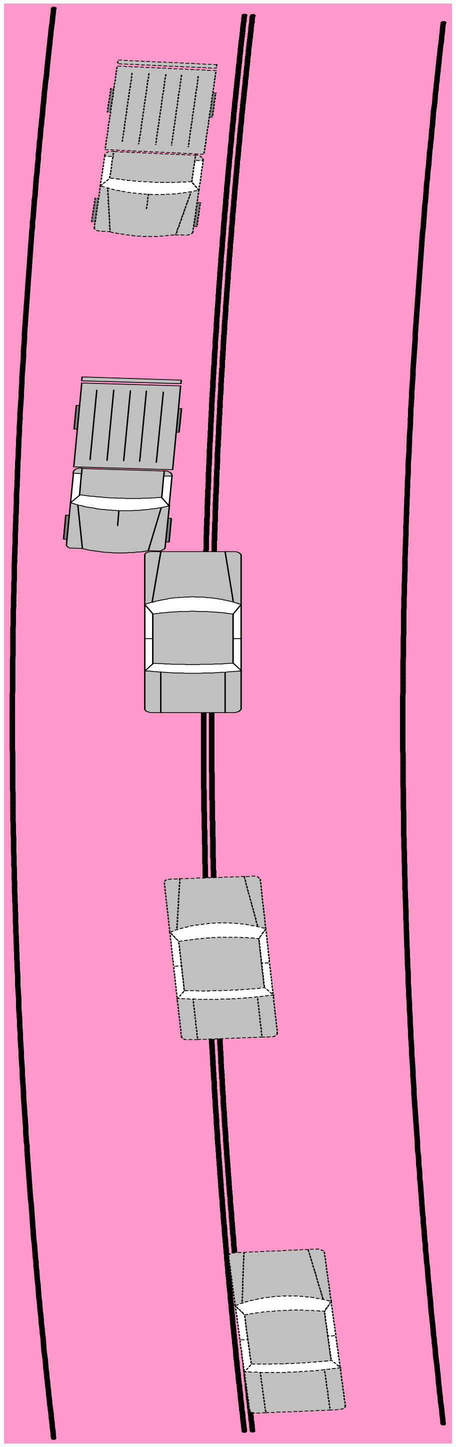
- 3rd column of CDC= F and 4th column of CDC = L or R

- 5th column of CDC = anything but W

- 6th column of CDC = E

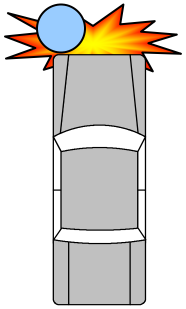
Direct Damage involves less than 41cm (16”) of the Front Plane <u>and</u> a corner

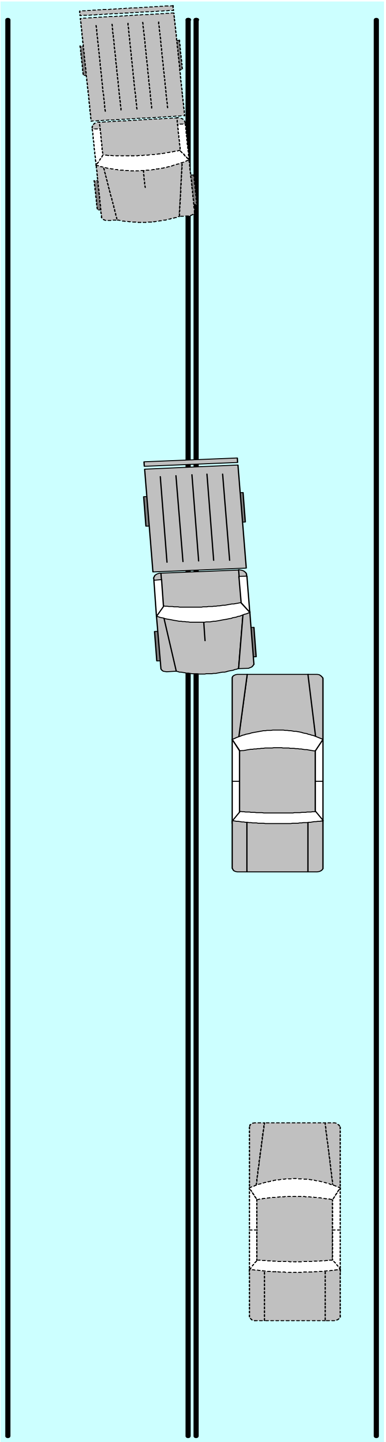




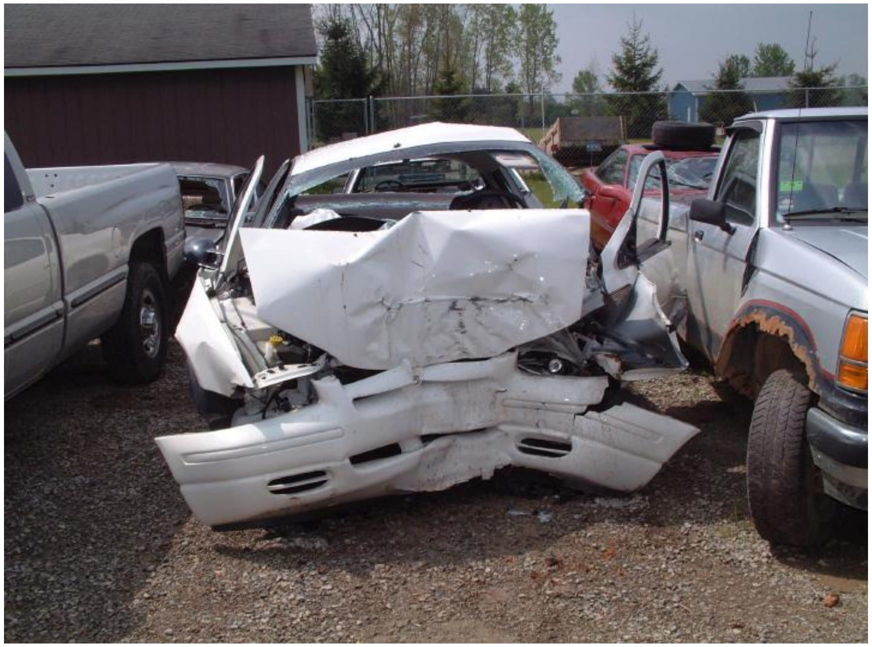
Extreme Off-set (Left or Right) Impacts:

Comparable with Narrow Rigid Object corner impacts





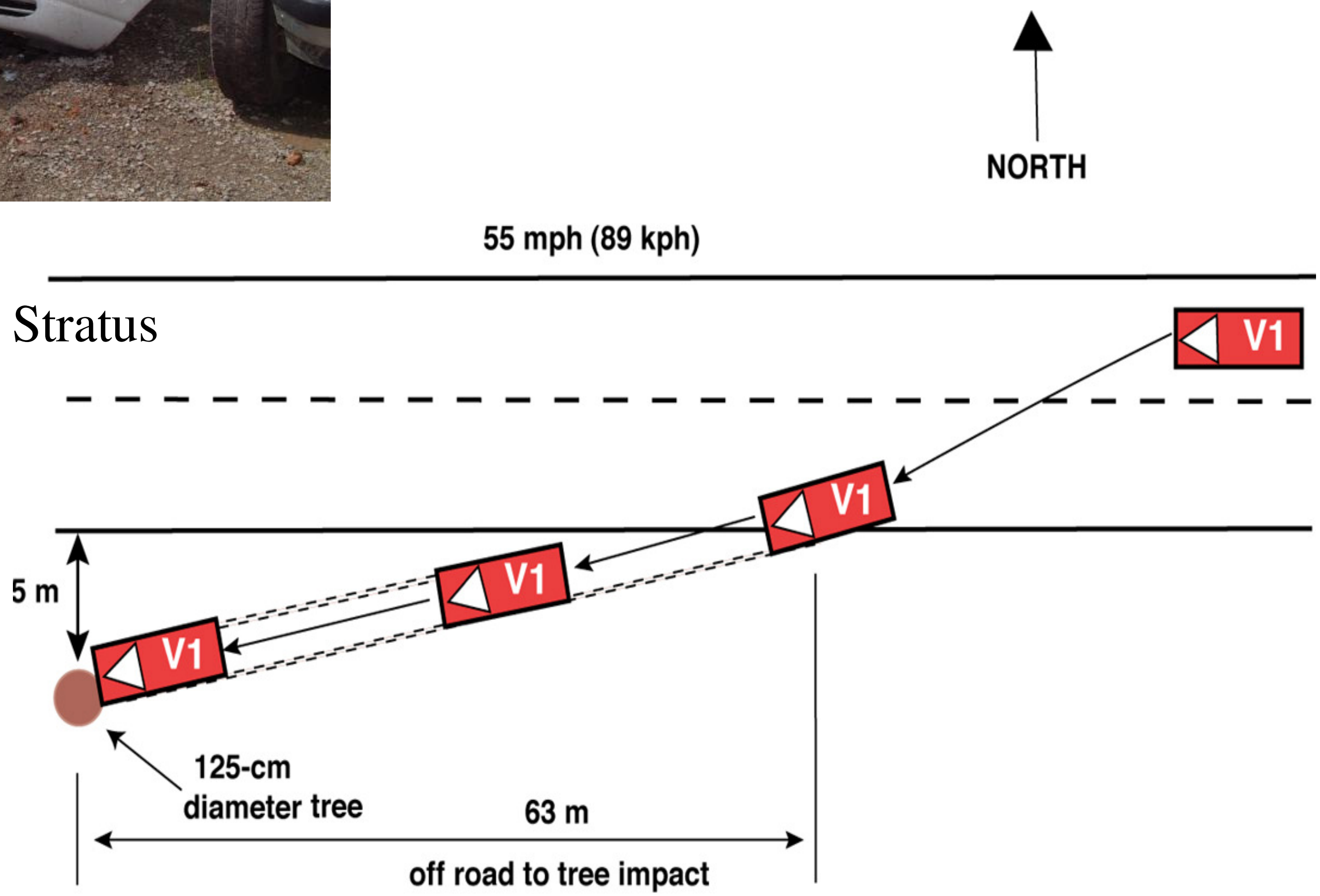
CIREN Investigations



Distributed Frontal Impact

Case vehicle: 2000 Dodge Stratus

Struck object: Big tree



Distributed Frontal Impact

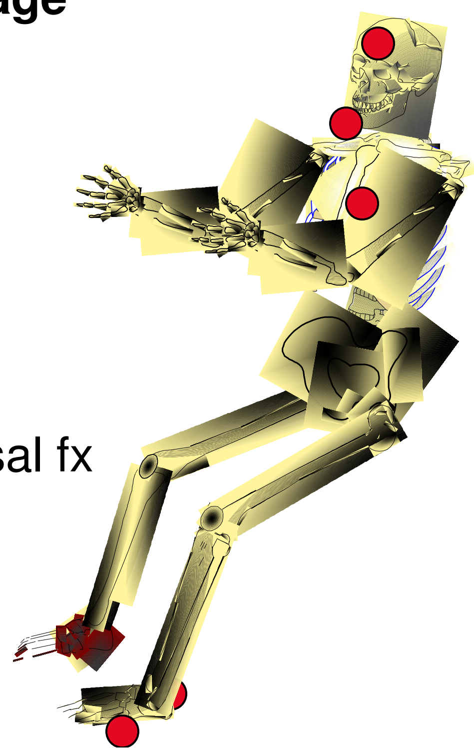
20 year old female driver Using safety belt and steering wheel air bag deployed

Right frontal and temporal lobe intraparenchymal hemorrhage
Right subarachnoid hemorrhage

Left mandibular fx

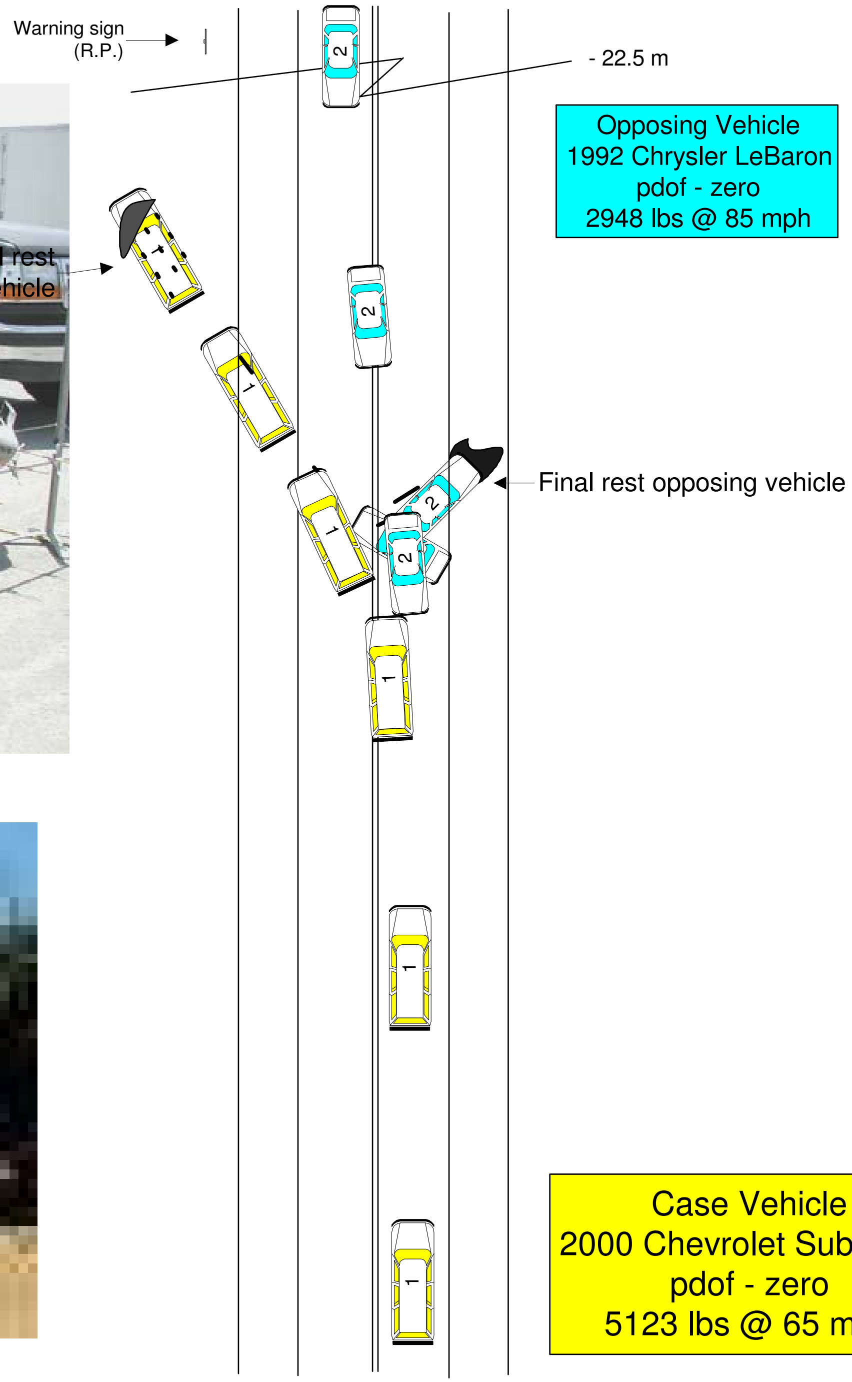
Right pulmonary contusion

Right subtalar dislocation
Right talar head and neck fx
Right cuneiform fx and metatarsal fx



Off-set Frontal Impact

2000 Chevrolet Suburban



Opposing Vehicle
1992 Chrysler LeBaron
pdof - zero
2948 lbs @ 85 mph

Case Vehicle
2000 Chevrolet Suburban
pdof - zero
5123 lbs @ 65 mph

Off-set Frontal Impact

Right comminuted distal femur fx

Left acetabular fx

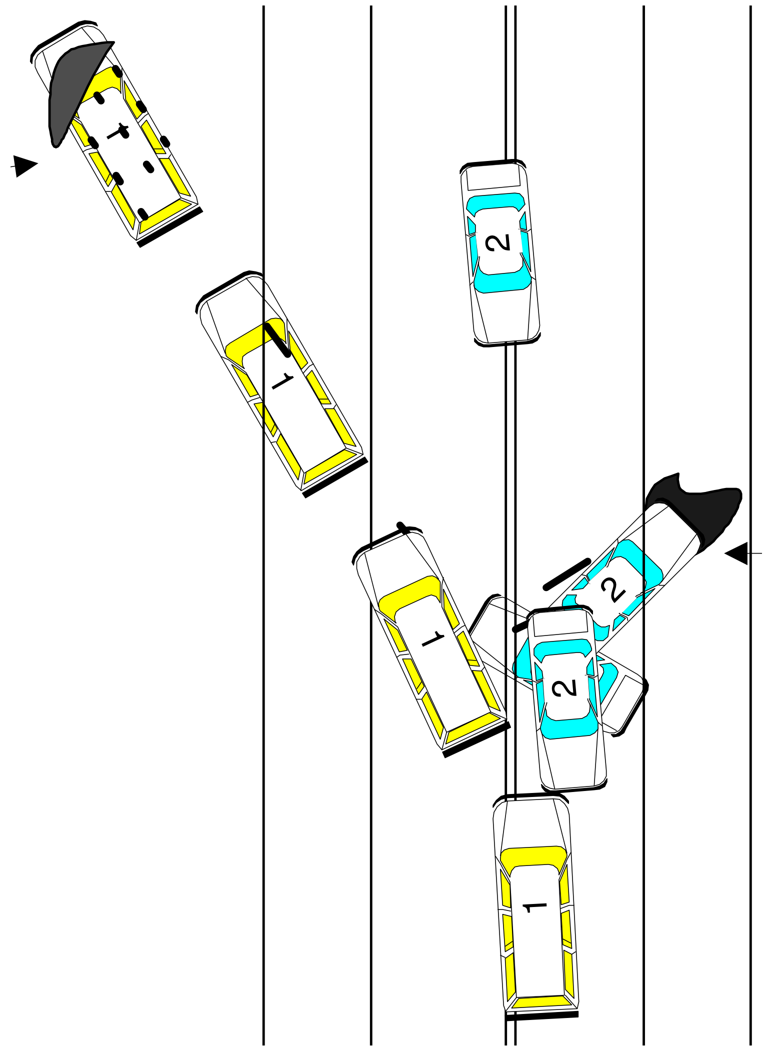
Concussion and scalp lac

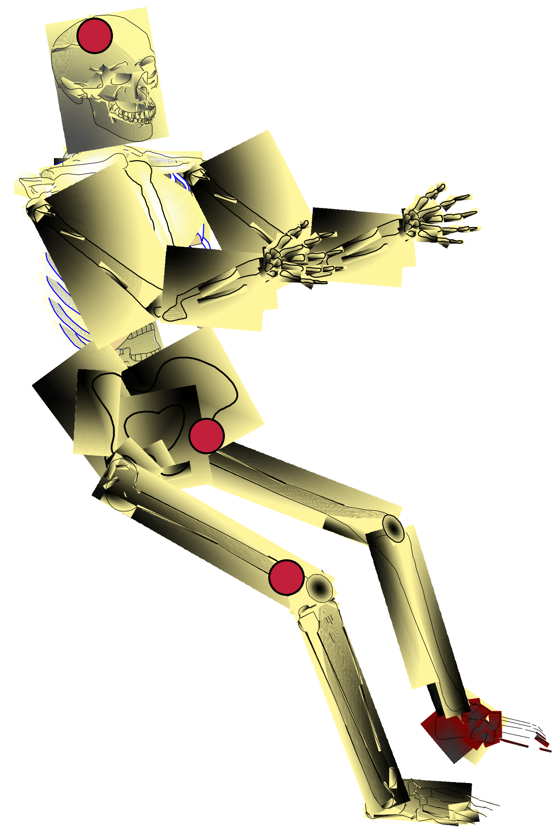
Front right seat passenger

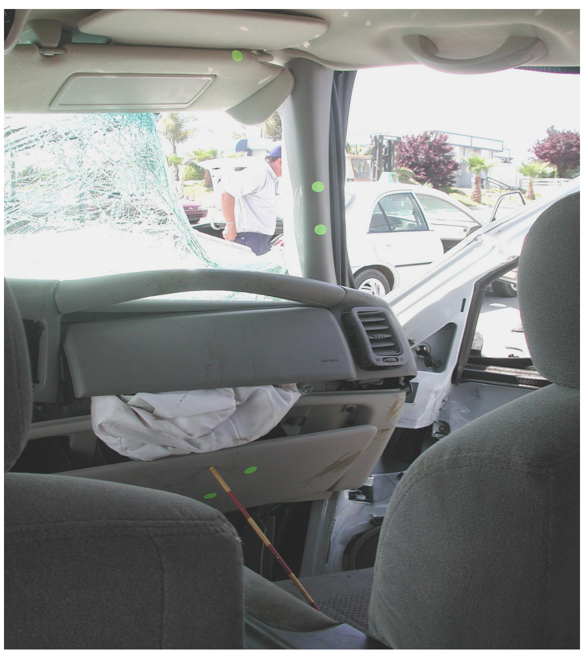
34 year old female

Wearing safety belt

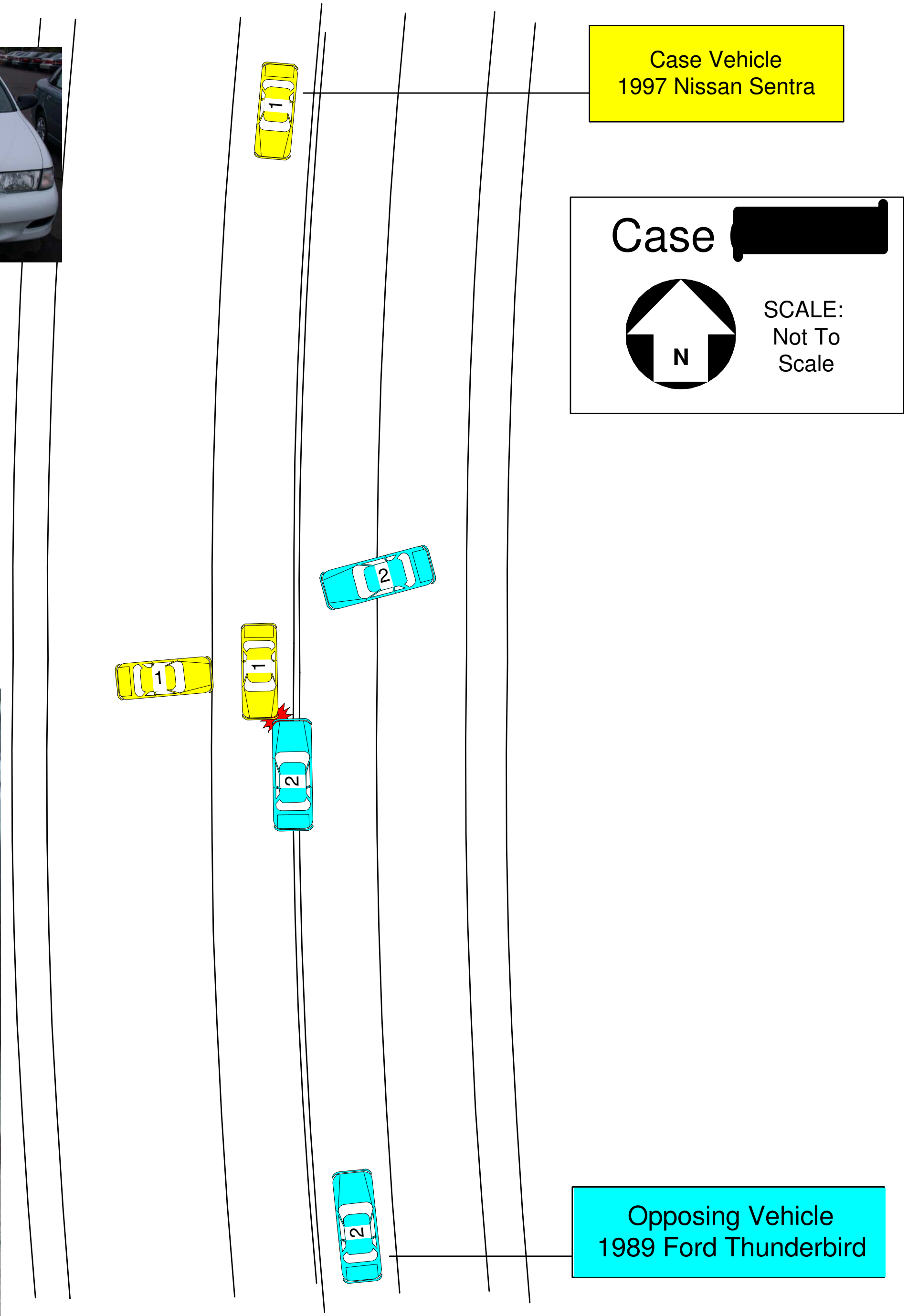
Front IP Air bag deployment







Corner Frontal Impact



Driver

35 year old male

Wearing safety belt

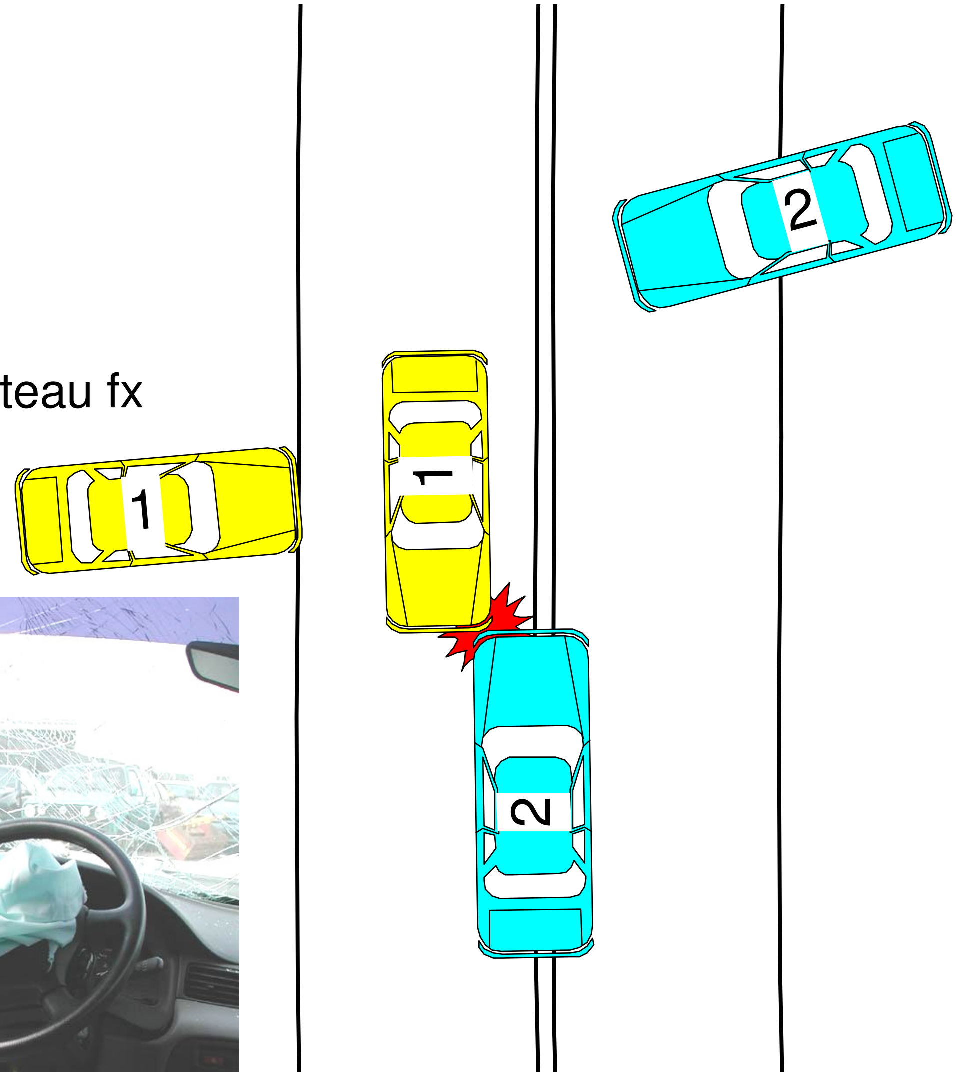
Steering wheel Air bag deployment

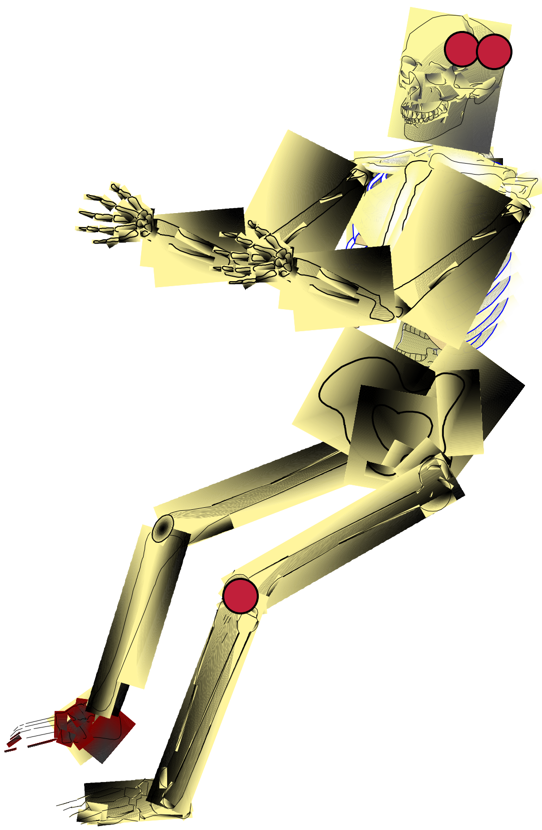
Injuries:

Left SAH

Left SDH

Left tibial plateau fx





UNIVERSITY *of* CALIFORNIA, SAN DIEGO
MEDICAL CENTER

CIREN Database

Used to compare brain injury patterns for Distributed, Off-set, Corner frontal impacts

- Severity
- Sources
- Types of brain injuries

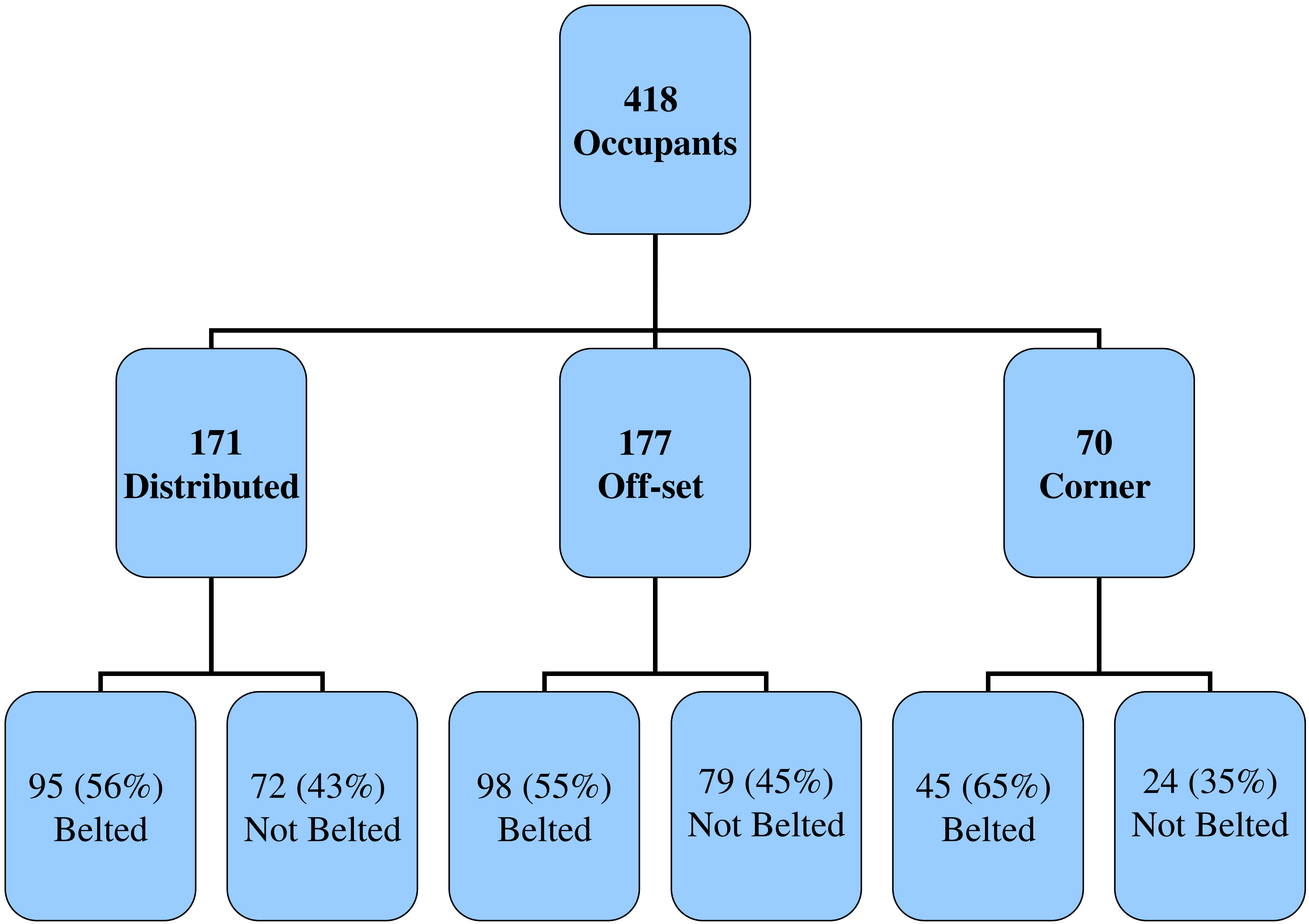
Study Inclusion Criteria

- AIS $\geq$ 2 brain injury severity
  - Scalp lacerations excluded
  - Cranial nerve injuries excluded
  - Secondary injury (e.g., compression) excluded
- First row drivers and outboard passengers
  - Adults (>13 years old)
- Frontal in-line impacts ranked #1
  - Only Distributed, Off-set, Corner impacts

Brain Injuries Studied

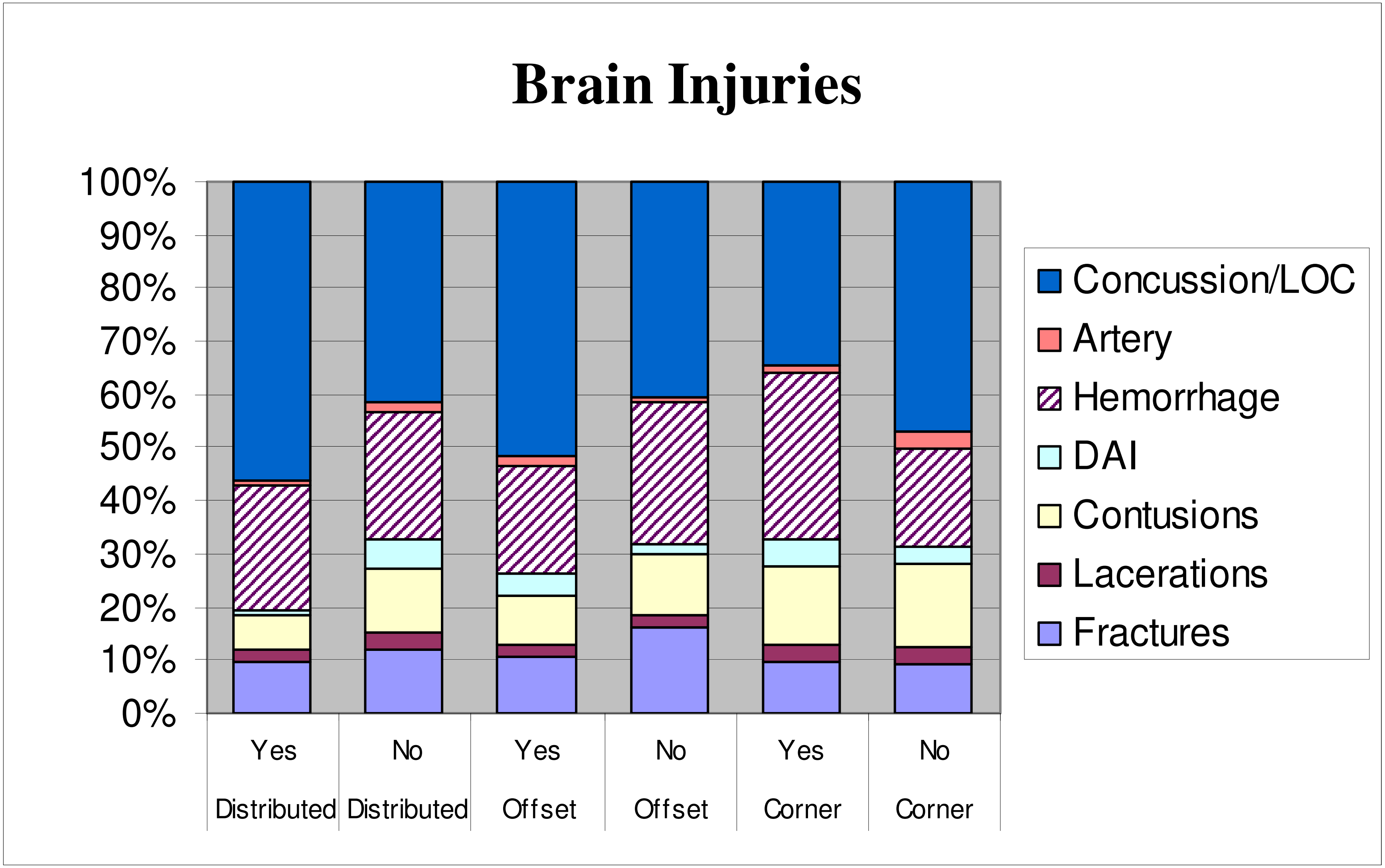
- **Skull fractures**
  - Vault, Base
- **Focal Injury**
  - **Hemorrhage**
    - Subdural
    - Epidural
    - Subarachnoid
    - Intracranial
  - **Contusions/Lacerations**
    - Cerebrum (Frontal, temporal/parietal, occipital), cerebellum
- **Diffuse Injury**
  - Diffuse Axonal Injury (DAI)
  - Concussion/Loss of Consciousness (LOC)

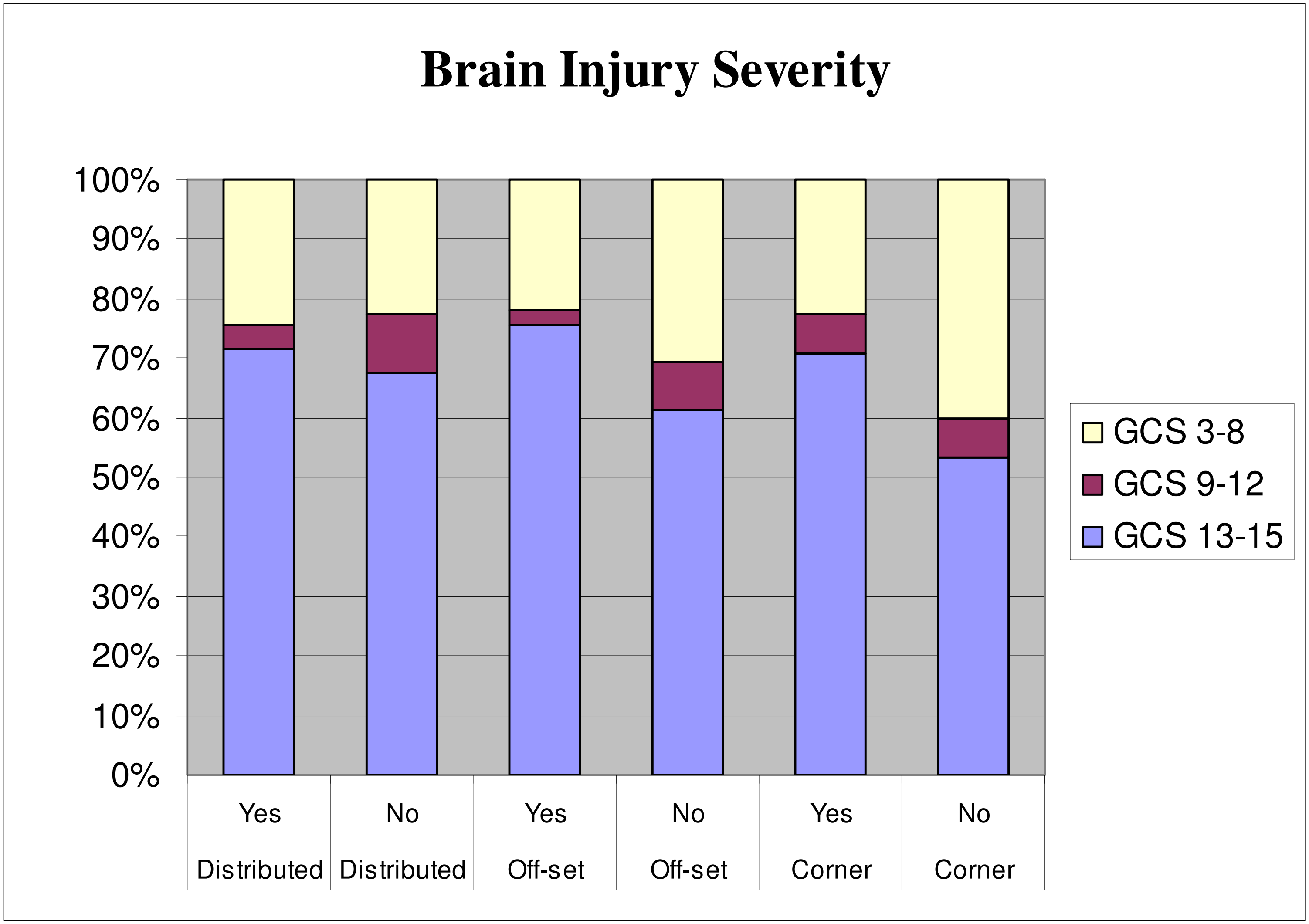
Occupants with Brain Injury

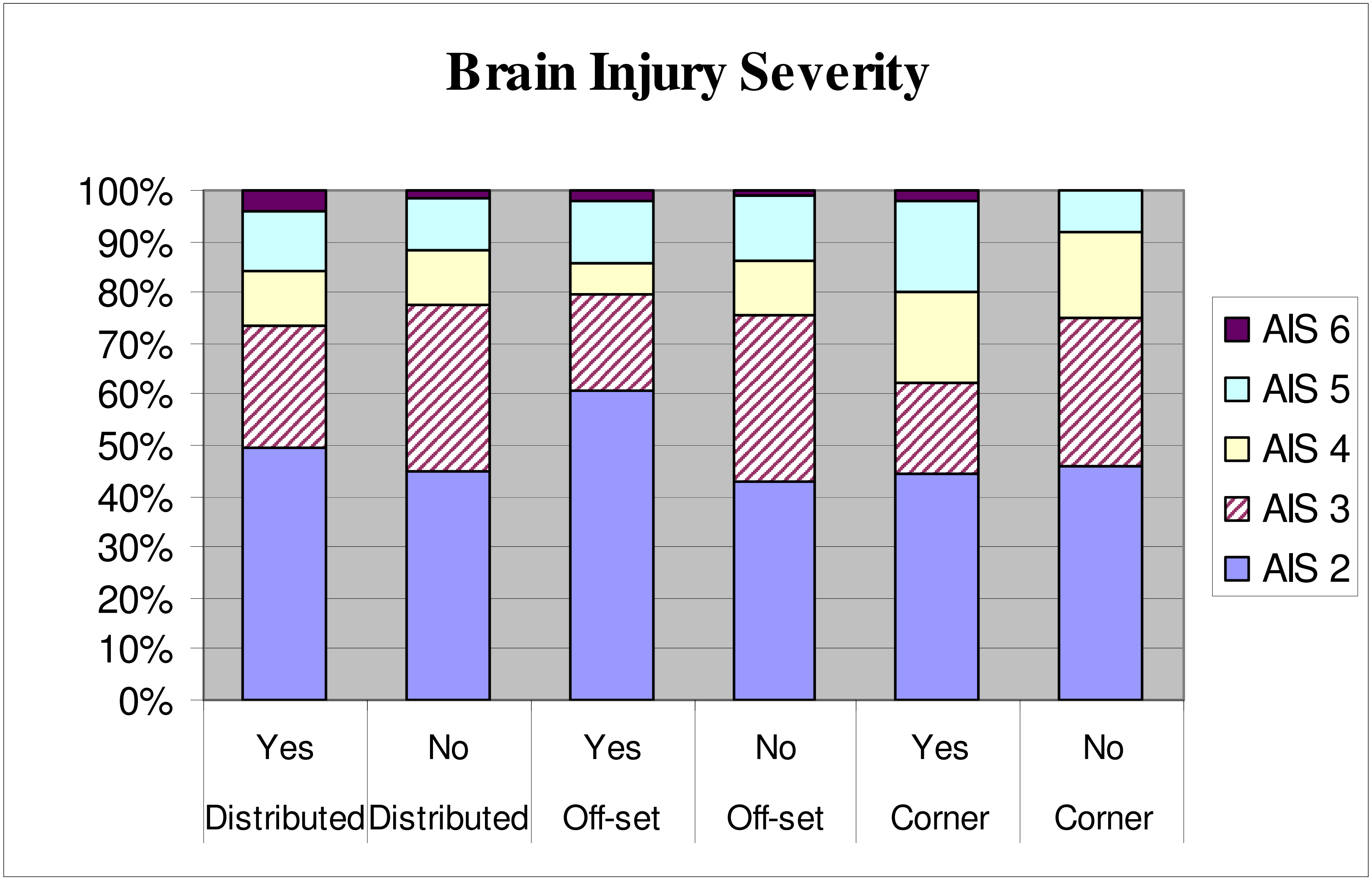


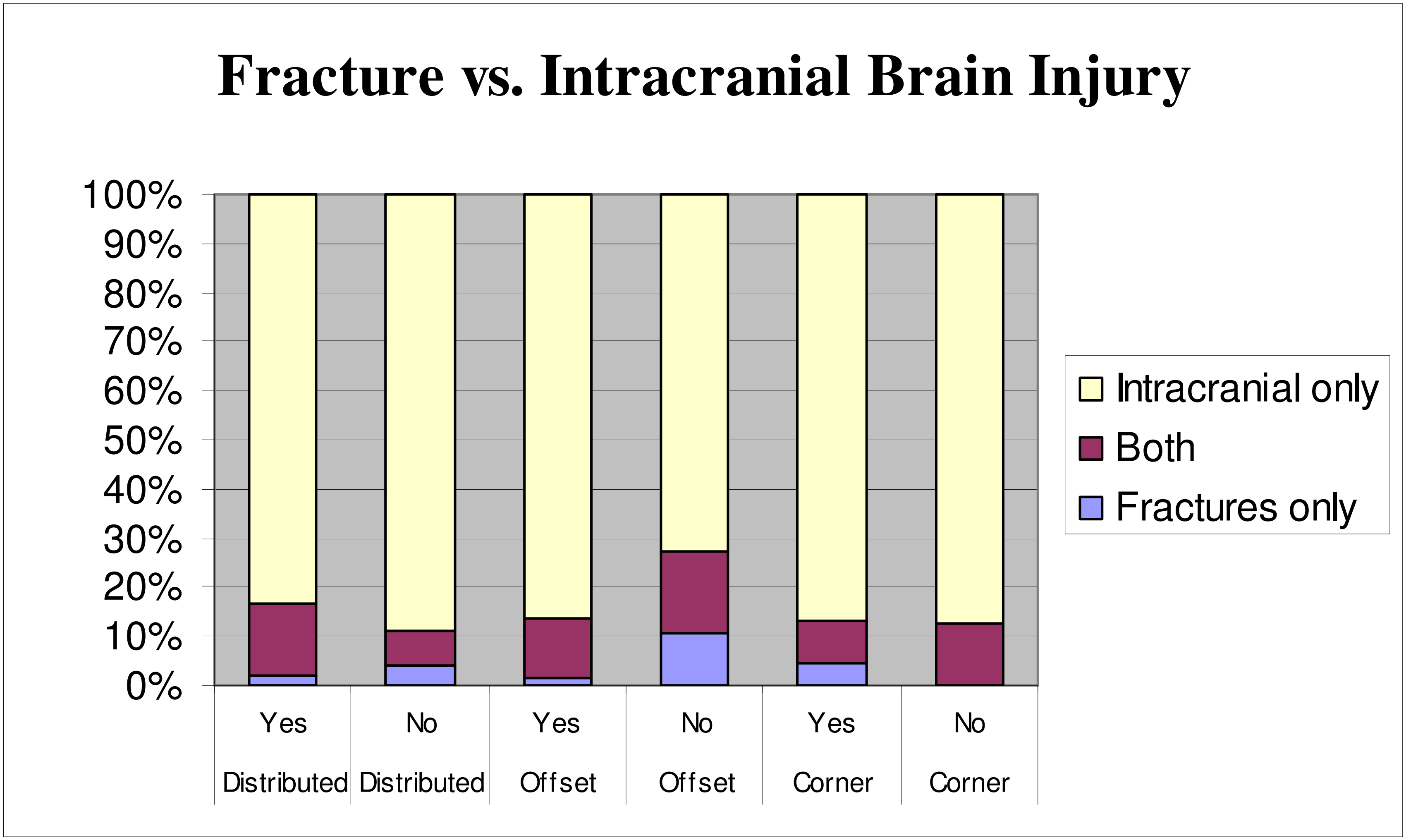
Characteristics of Occupants with Brain Injury

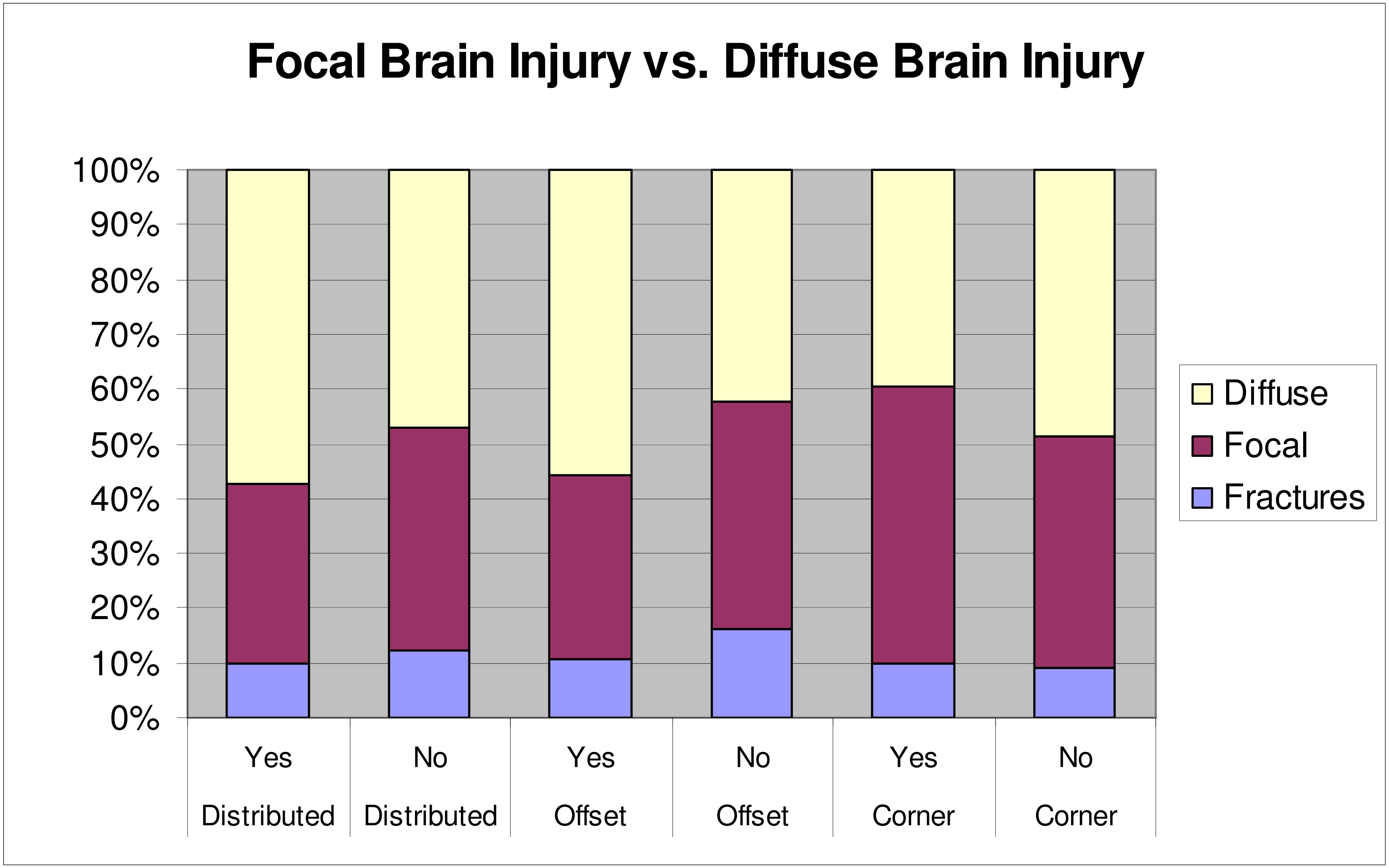
	Distributed	Off-set	Corner
Age (years)			
Mean	40	40	41
Median	37	36	35
Range	13 - 86	13 - 85	16 - 94
delta V (kmph)			
Mean	51	49	30
Median	47	46	25
Range	15 - 137	12 - 126	12 - 94
Safety belt used	56.2%	55.4%	65.2%
Front bag deployed	94%	96%	96%
Male	49.4%	57.5%	64.7%
Driver	81.9%	85.3%	87.1%


Brain Injuries
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Concussion/LOC
Artery
Hemorrhage
DAI
Contusions
Lacerations
Fractures
Yes Distributed
No Distributed
Yes Offset
No Offset
Yes Corner
No Corner

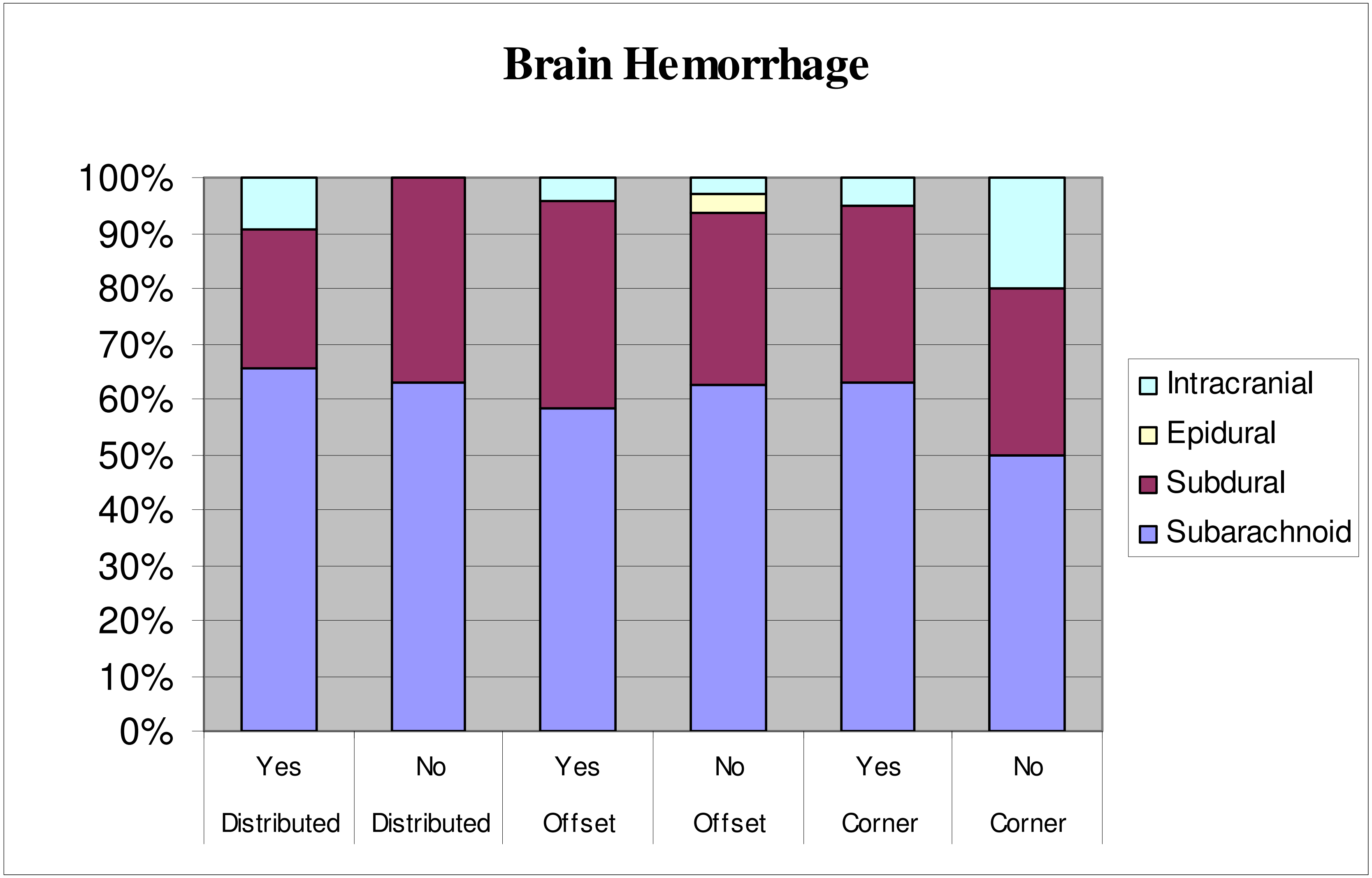

Brain Injury Severity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Off-set
No Off-set
Yes Corner
No Corner
GCS 3-8
GCS 9-12
GCS 13-15

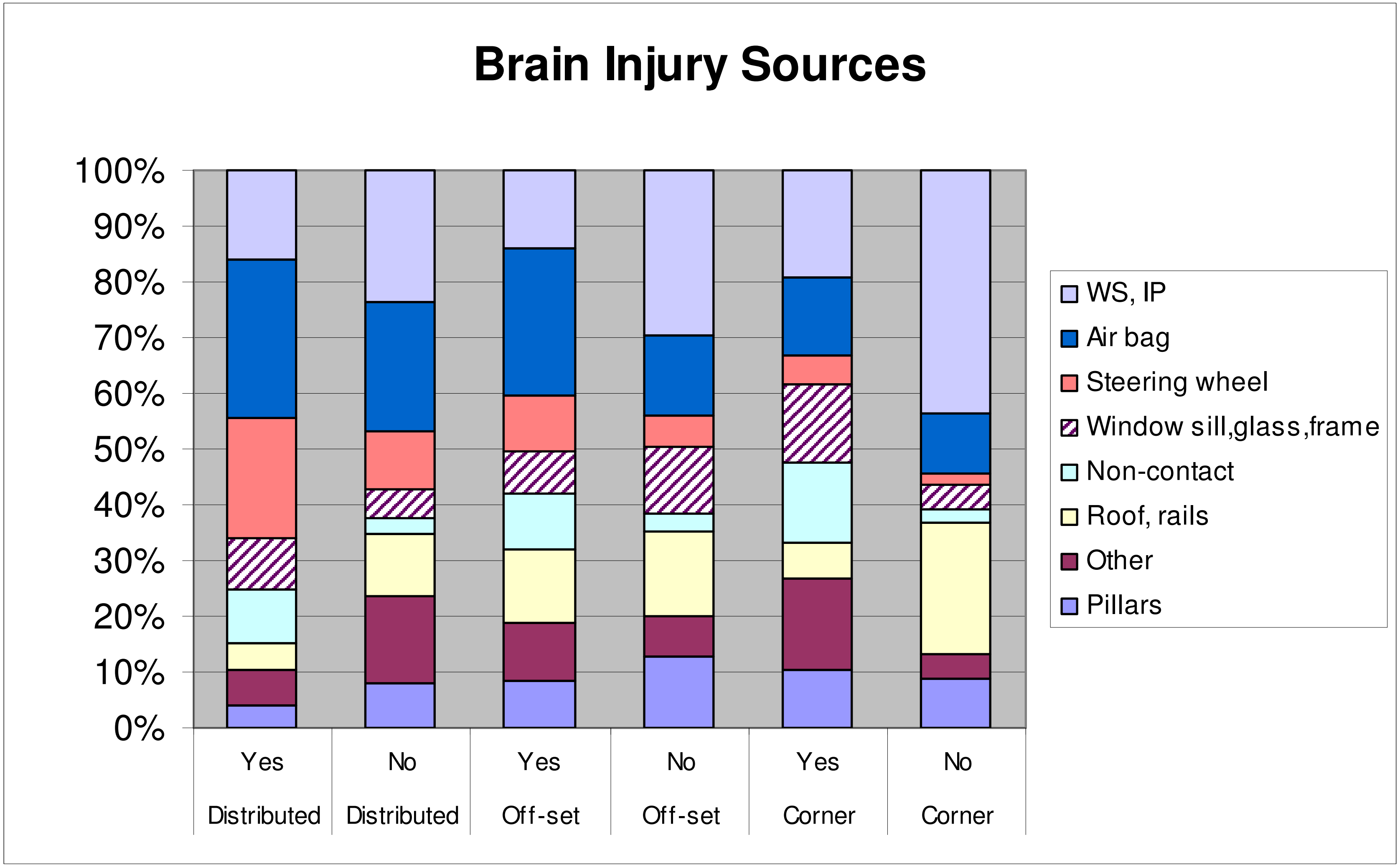

Brain Injury Severity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Off-set
No Off-set
Yes Corner
No Corner
AIS 6
AIS 5
AIS 4
AIS 3
AIS 2


Fracture vs. Intracranial Brain Injury
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Offset
No Offset
Yes Corner
No Corner
Intracranial only
Both
Fractures only



Focal Brain Injury vs. Diffuse Brain Injury
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Diffuse
Focal
Fractures
Yes
Distributed
No
Distributed
Yes
Offset
No
Offset
Yes
Corner
No
Corner


Brain Hemorrhage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Offset
No Offset
Yes Corner
No Corner
Intracranial
Epidural
Subdural
Subarachnoid


Brain Injury Sources
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Off-set
No Off-set
Yes Corner
No Corner
WS, IP
Air bag
Steering wheel
Window sill,glass,frame
Non-contact
Roof, rails
Other
Pillars

Conclusions

- Restraint use (wearing safety belt) may influence sources of brain injuries for all types of frontal impacts studied
  - Restrained: More non-contact brain injuries
  - Unrestrained: More hard-contact brain injuries caused by roof, roof rails, windshield, instrument panel
- Corner impacts may have different sources of injury (more hard contact with the windshield and instrument panel) compared to distributed and off-set frontal impacts (more soft contact air bag related brain injuries)
- Brain injuries from corner impacts were more severe (based on GCS and more intracranial hemorrhage)
- Suggests head model incorporating angular acceleration may be important for crash testing
- Supports use of CIREN data and "real world" crash investigations to study brain injuries

UNIVERSITY of CALIFORNIA, SAN DIEGO
MEDICAL CENTER

San Diego CIREN Team

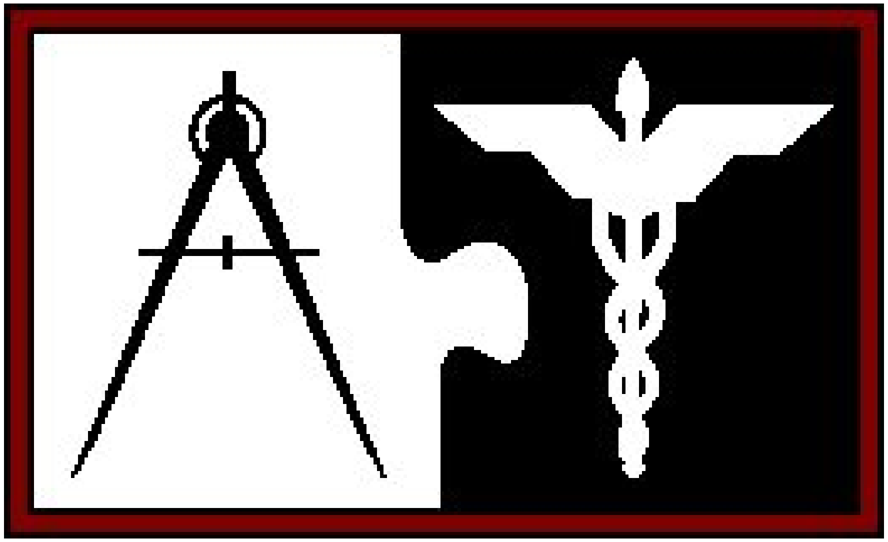
Principal Investigators

Raul Coimbra, MD, PhD, FACS (University of California at San Diego)
Gail T. Tominaga, MD, FACS (Scripps Memorial Hospital, La Jolla)

Team

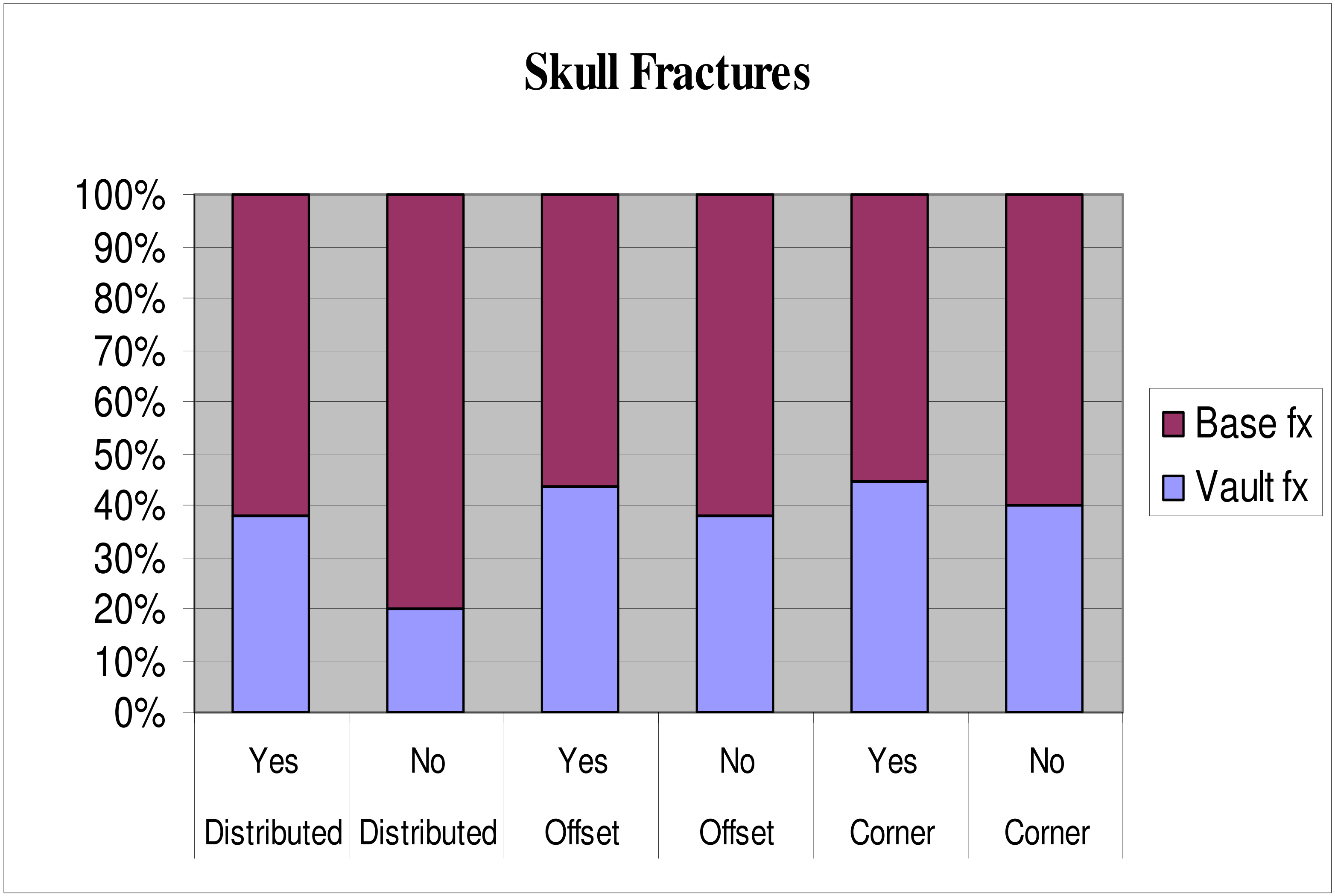
Sharon Pacyna, RN, BSN, MPH
Steve Erwin
Carol Conroy, MPH, PhD
MarSue May, RN, BSN
Barbara Frasier

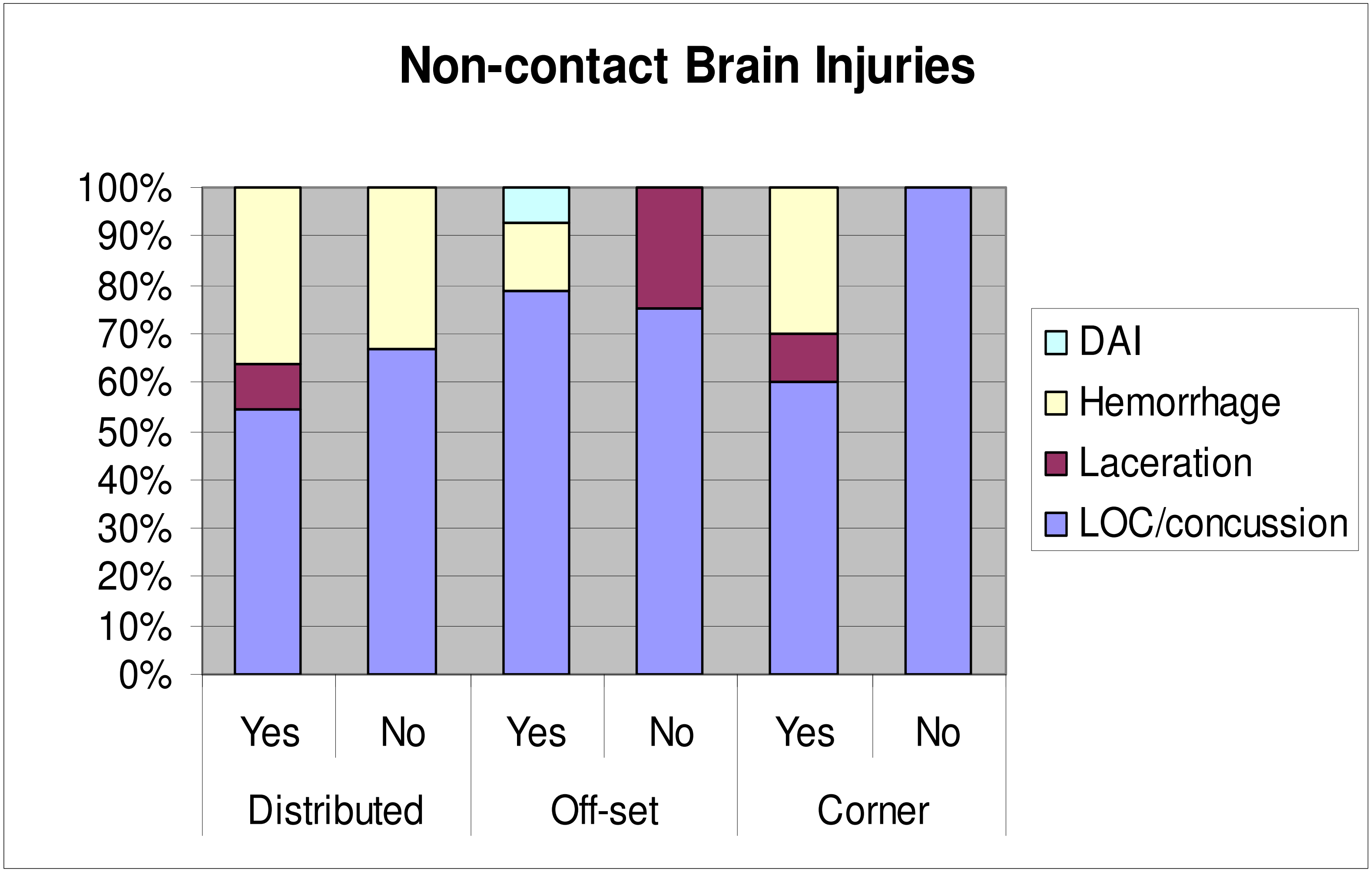
Questions?

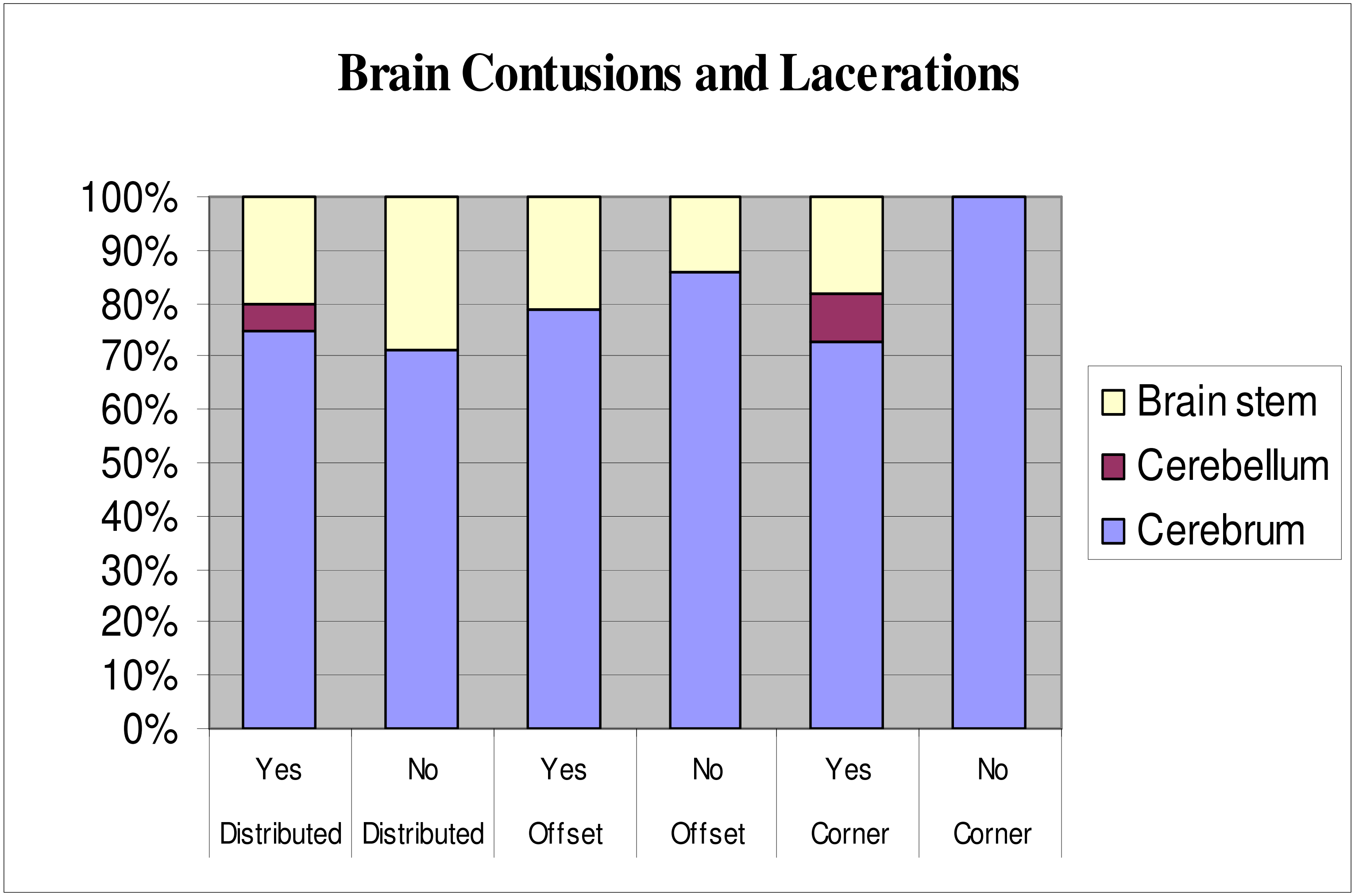


UNIVERSITY *of* CALIFORNIA, SAN DIEGO
MEDICAL CENTER

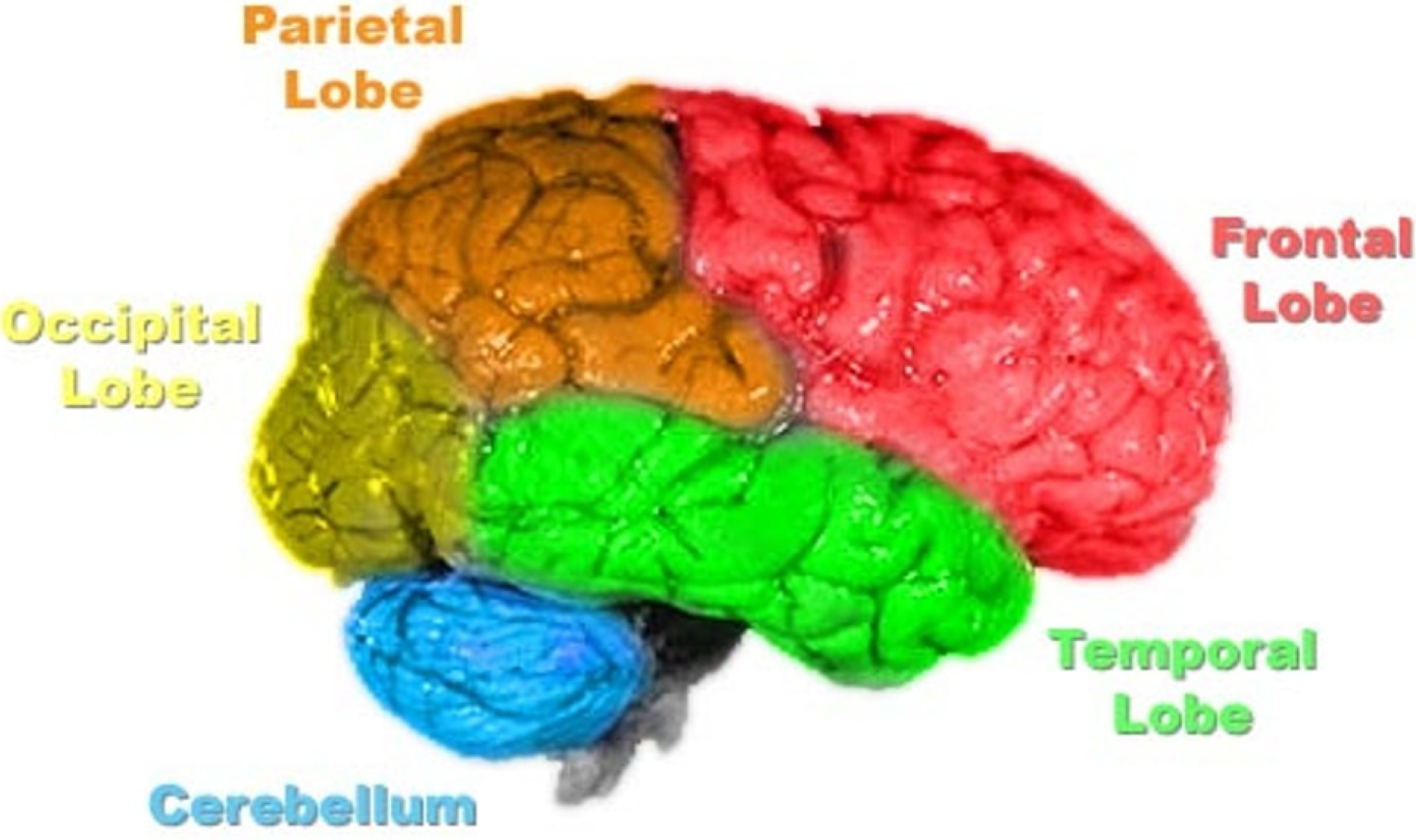
Unused slides


Skull Fractures
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Offset
No Offset
Yes Corner
No Corner
Base fx
Vault fx


Non-contact Brain Injuries
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No
Yes
No
Yes
No
Distributed
Off-set
Corner
DAI
Hemorrhage
Laceration
LOC/concussion


Brain Contusions and Lacerations
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes Distributed
No Distributed
Yes Offset
No Offset
Yes Corner
No Corner
Brain stem
Cerebellum
Cerebrum

Parietal
Lobe
Frontal
Lobe
Occipital
Lobe
Temporal
Lobe
Cerebellum


Parietal
Lobe
Frontal
Lobe
Occipital
Lobe
Temporal
Lobe
Cerebellum