

HEAD INJURIES: HOW TO PROTECT WHAT

SNELL CONFERENCE ON HIC

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INJURY:

The result of the application of mechanical energy above the ability of the tissue to withstand it without anatomical or physiological alteration.

BRAIN INJURY IS NOT UNIDIMENSIONAL!!

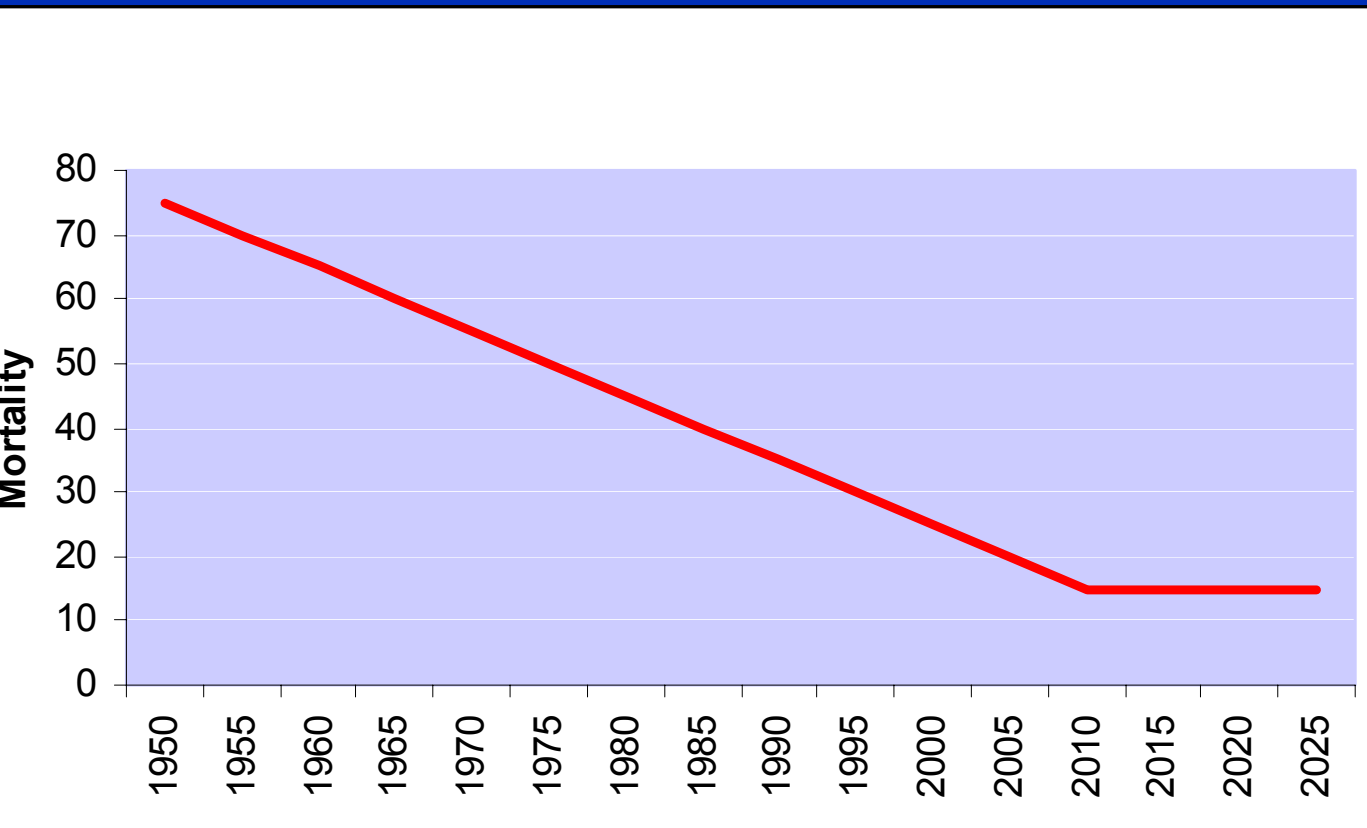
- **DIFFERENT CAUSES**
- **DIFFERENT MECHANISMS**
- **DIFFERENT TYPES**
- **DIFFERENT AMOUNTS**
- **DIFFERENT LOCATIONS**
- **DIFFERENT PATHOPHYSIOLOGY**
- **DIFFERENT TREATMENTS**

SO IS ONE TOLERANCE REASONABLE?????

What are we trying to prevent?

- **Which TBI are “acceptable?”**
- **Which TBI are unacceptable?**
- **Are these the same for all circumstances?**
- **Given the advances in the last 50 years. Don't we have to lower the bar and prevent more TBI?**

Mortality of severe TBI

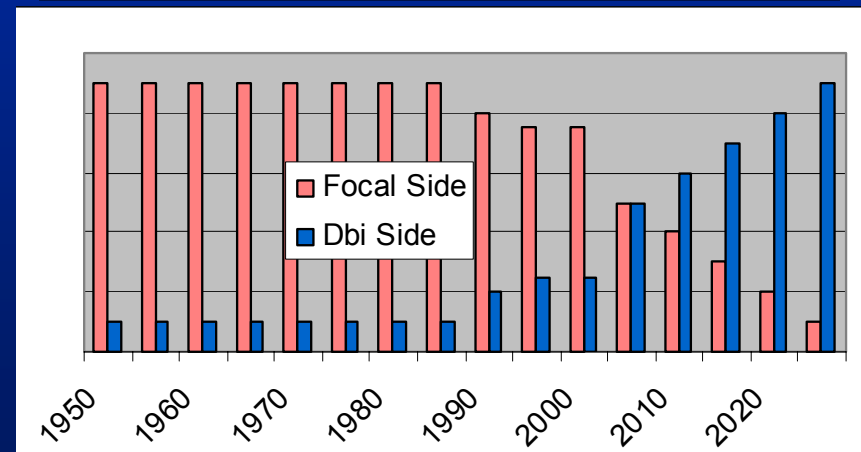
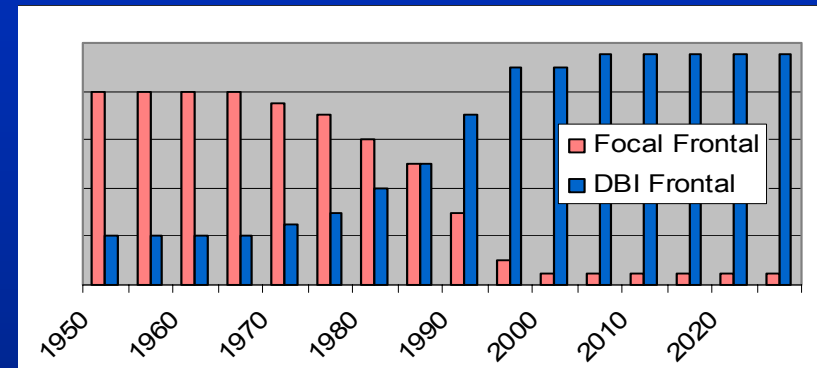


- Uniform injury descriptors; improved care; trauma care systems
- GCS: Teasdale, Jennett 1974
- Widespread adoption of GCS, Langfitt, Gennarelli 1982

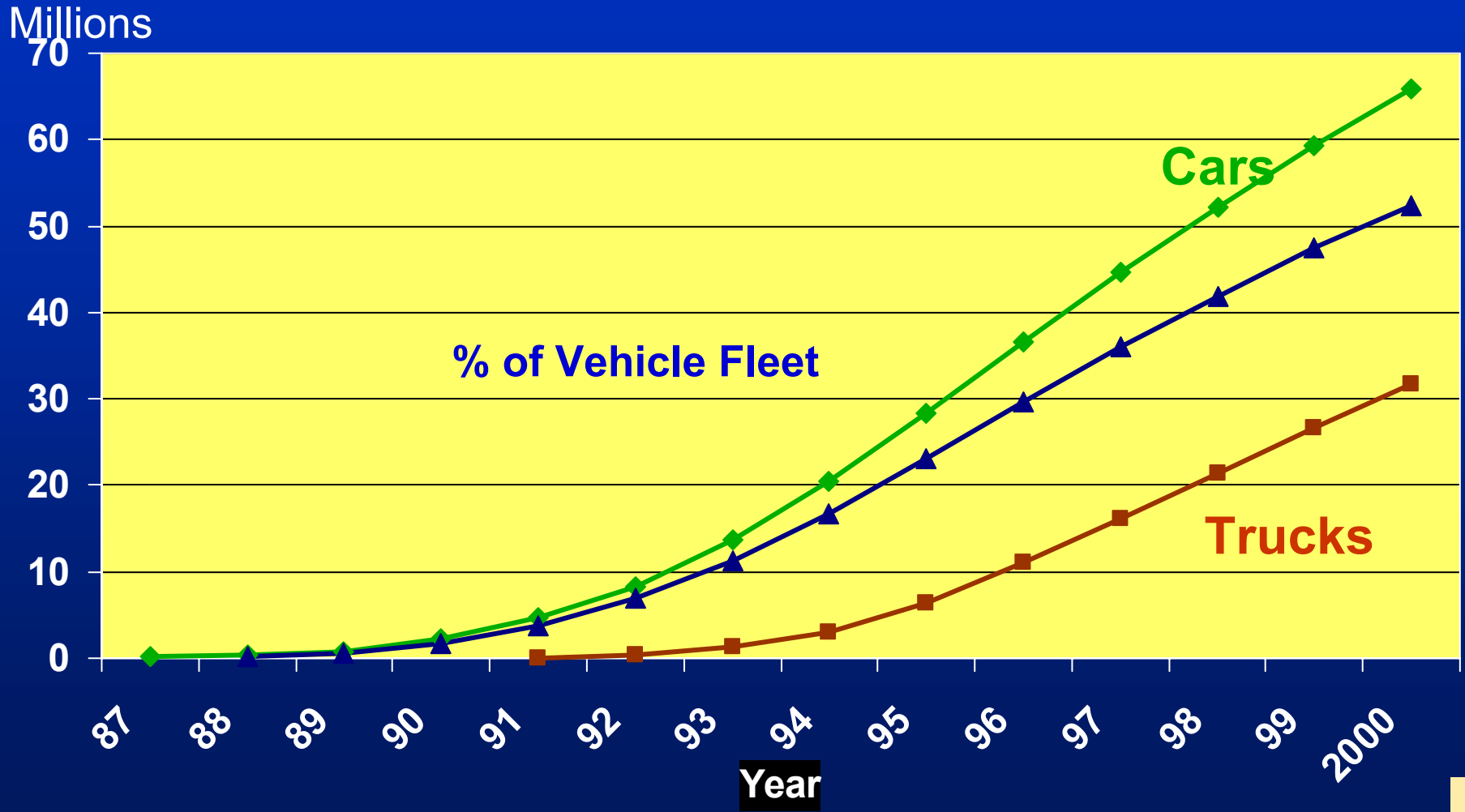
Importance of Biomechanics

- Shift of TBI type
- Shift of TBI severity
- Reduction of mortality
- Potential of virtual elimination of severe TBI in certain situations

Vehicular Head Injuries



Number of Vehicles with Airbags



Future of TBI

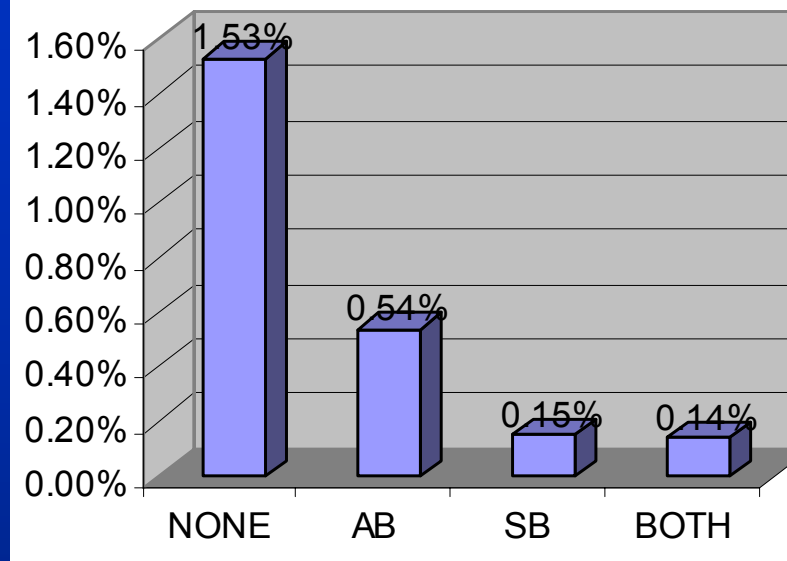
The chances of getting an AIS 4-6 head injury when restrained with seat belt and airbag are very small in a frontal crash .. 0.14%.

So if all 1.5M frontal occupants had SB+AB:

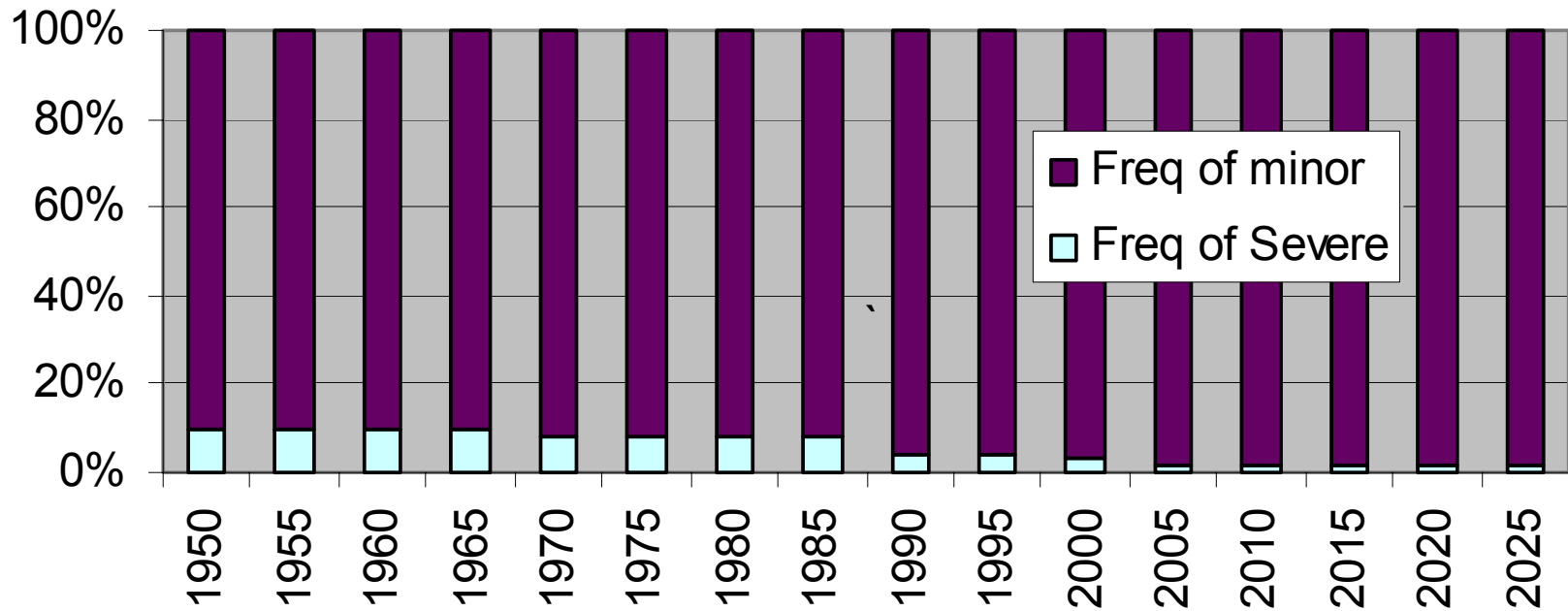
• $1.5 * 0.14\% = 2100/\text{yr} = 1$
per hospital per year

• IF A SERIOUS HEAD INJURY OCCURS, IT WILL BE AT FAR HIGHER CRASH SPEEDS THAN WITH OTHER RESTRAINT SYSTEMS.

Serious Head Injuries (AIS 4-6)



Minor TBI will be more important

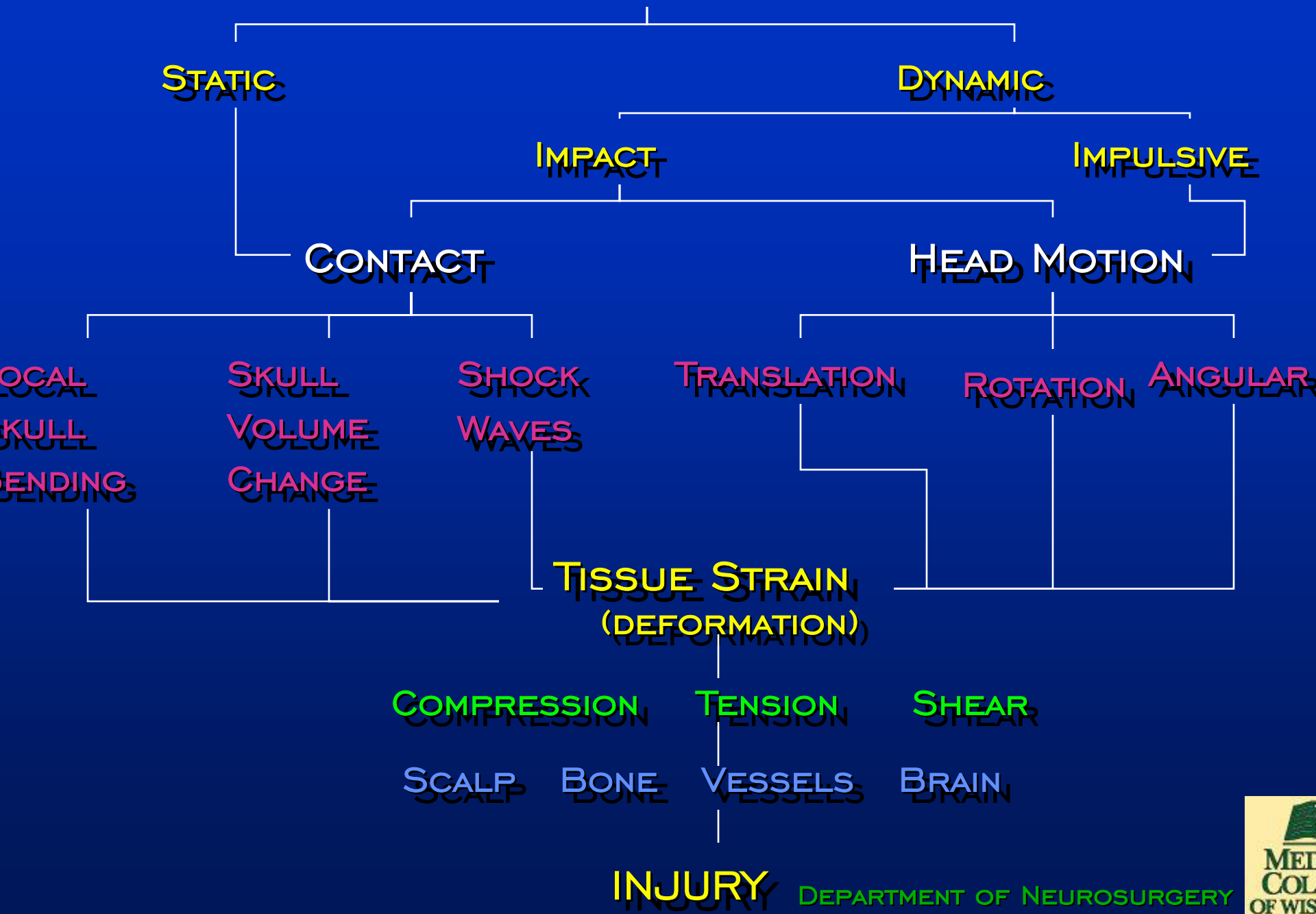


So, DO WE NEED TO THINK ABOUT PREVENTING MTBI?

TYPES OF HEAD INJURY

- SCALP LACERATIONS
- SKULL FRACTURES
- FOCAL BRAIN INJURIES
 - CONTUSION, LACERATION
 - HEMORRHAGE: EDH, SAH, SDH, ICH
- DIFFUSE BRAIN INJURIES
 - CONCUSSION SYNDROMES
 - DIFFUSE AXONAL INJURY
- PENETRATING INJURIES
- BLAST-EXPLOSIVE INJURIES

MECHANICAL LOADING



Mechanisms of the Head Injuries

• Contact Injuries

- Skull Fracture
- Epidural Hematoma
- Coup Contusion
- ICH
- Penetrating Inj.

• Head Motion Injuries

- Contre Coup Contusion
- Subdural Hematoma
- Concussion
- Diffuse Axonal Injury

HEAD CONTACT INJURIES

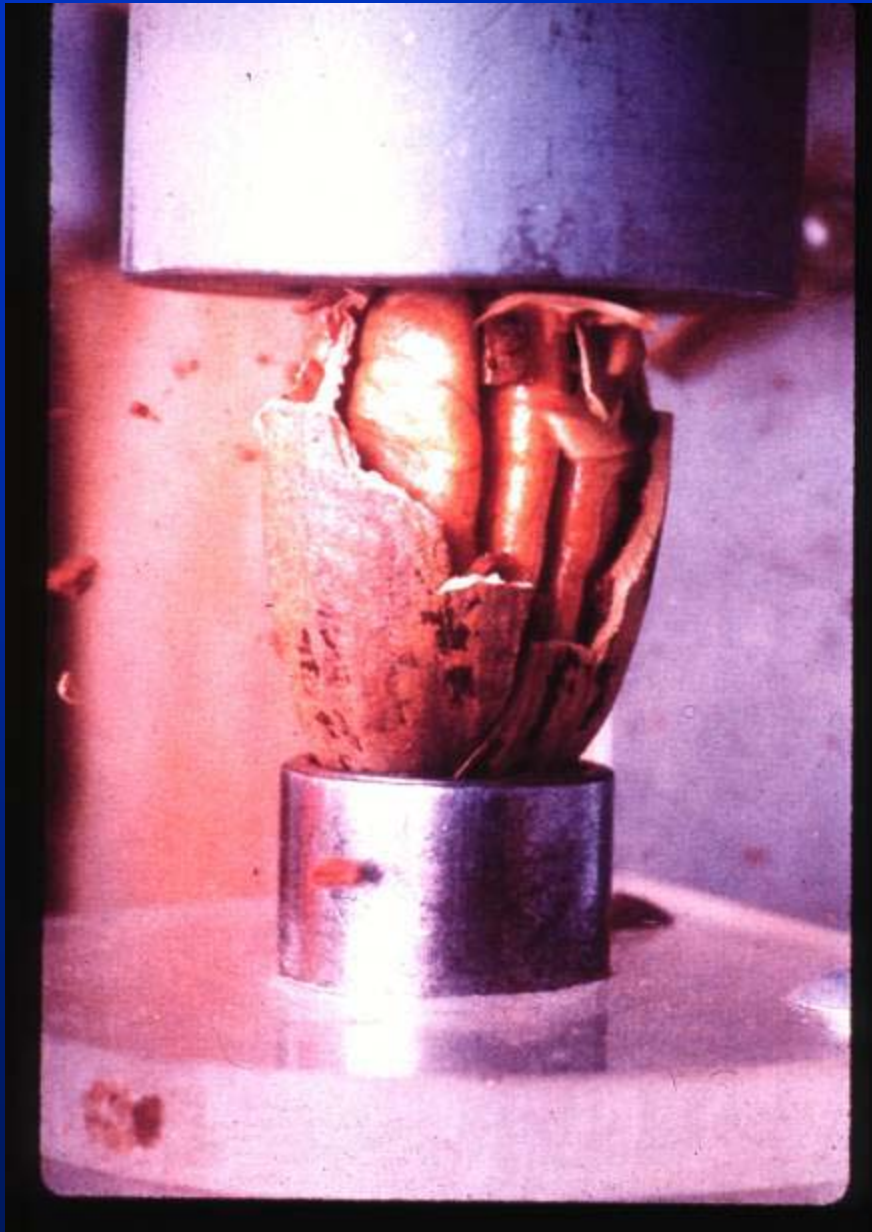
MOTION NOT REQUIRED; DIRECT BLOW NECESSARY

- **Skull Bending**
 - **Skull Fracture**
 - **Coup Contusion**
- **Skull Volume Changes**
 - **Contre Coup Contusion**
- **Shock Waves**
 - **Intracerebral Hemorrhage**
 - **Penetrating (Missile) injury**

HEAD MOTION INJURIES

motion required: direct blow not necessary

- **SURFACE STRAINS**
 - **SUBDURAL HEMATOMA**
 - **CONTRE COUP CONTUSION**
- **DEEP STRAINS**
 - **CONCUSSION SYNDROMES**
 - **DIFFUSE AXONAL INJURY**



**WHEN YOU BREAK THE
WHEN YOU BREAK THE
SKULL, THE BRAIN MAY
SKULL, THE BRAIN MAY
REMAIN INTACT.
REMAIN INTACT.**

Isolated HI Lesions

Lesion	n	% single
CSDH	24	70.8
Concussion	199	26.6
DAI - sev	17	23.5
DAI mod	57	22.8
Ped Swelling	28	17.9
ICH	33	9.1
Scalp	144	6.9
ASDH	67	3.0
Fx Vault	128	1.6
Contusion	135	1.5

INCIDENCE OF INJURIES

	OCCUPANT	PEDESTRIAN	NON-VEHICULAR
SKULL FRACTURE			
VAULT	25	40	39
BASILAR	21	18	12
DIFFUSE INJURY			
CONCUSSION	43	49	45
MODERATE DAI	22	50	2
SEVERE DAI	13	1	1
FOCAL INJURY			
CONTUSION	33	25	32
ALL SDH	16	8	18
SDH main injury	4	5	9
EDH	4	22	8
ICH	3		12

Skull Fracture Incidence

Percent

	Occupants	Pedestrians	Non-Vehicular
Concussion	29	52	50
Moderate DAI	46	32	50
Severe DAI	30	50	0
SDH	45	75	52
Contusion	53	60	58

Diffuse Brain Injury Categories

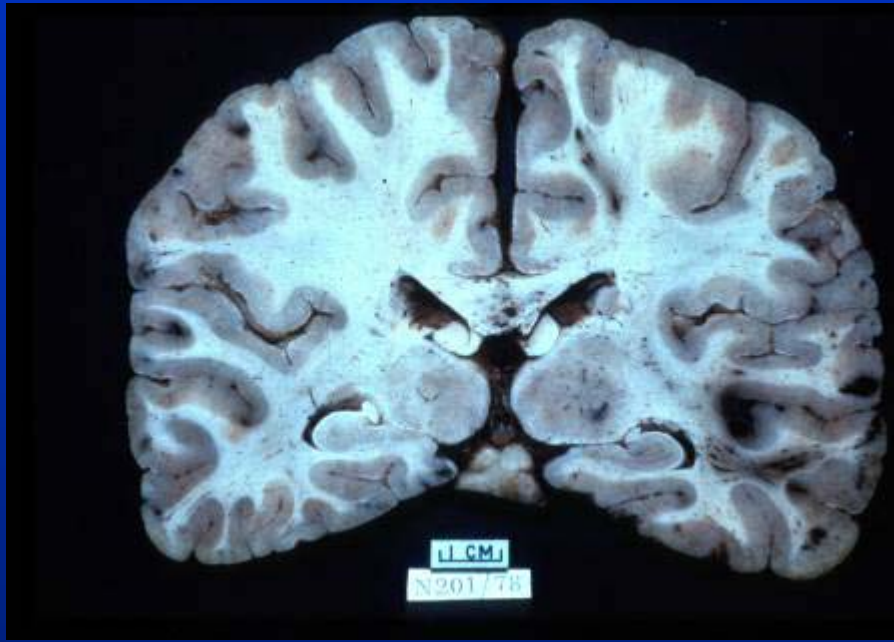
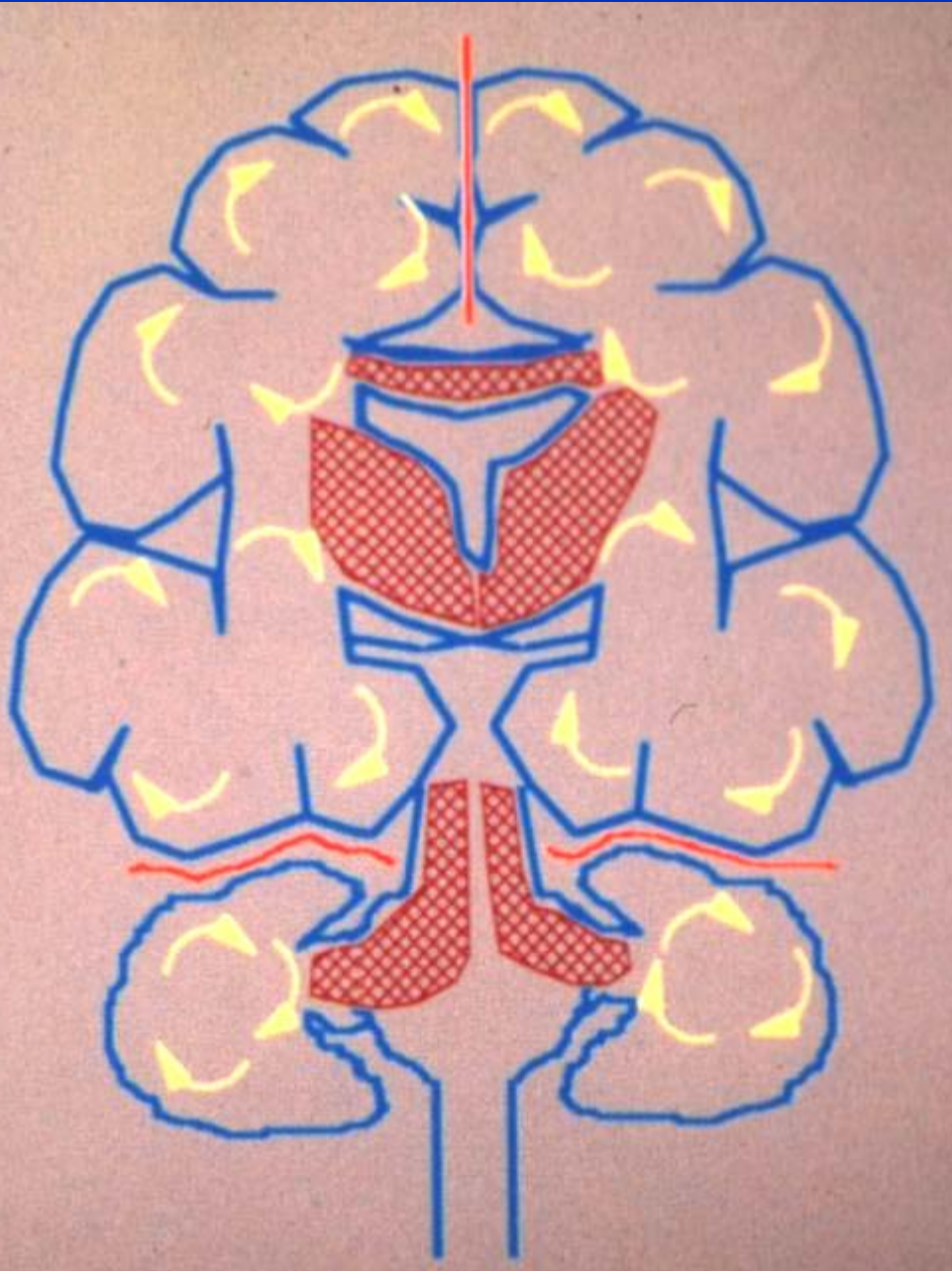
Abbreviation	Adjective	AIS	Ommaya Gennarelli Concussion Grade ¹	LOC
MC	Mild Concussion	1	1-3	0
CC	Classical Concussion	2	4	<1hr
SC	Severe Concussion	3	4	1-6 hr
Mild DAI	Mild DAI	4	5	6-24 hr
Moderate DAI	Moderate DAI	5	5	> 24 hr
Severe DAI	Severe DAI	5	5	>24 hr ^b

a = no brainstem abnormality; b = with decerebration, decortication

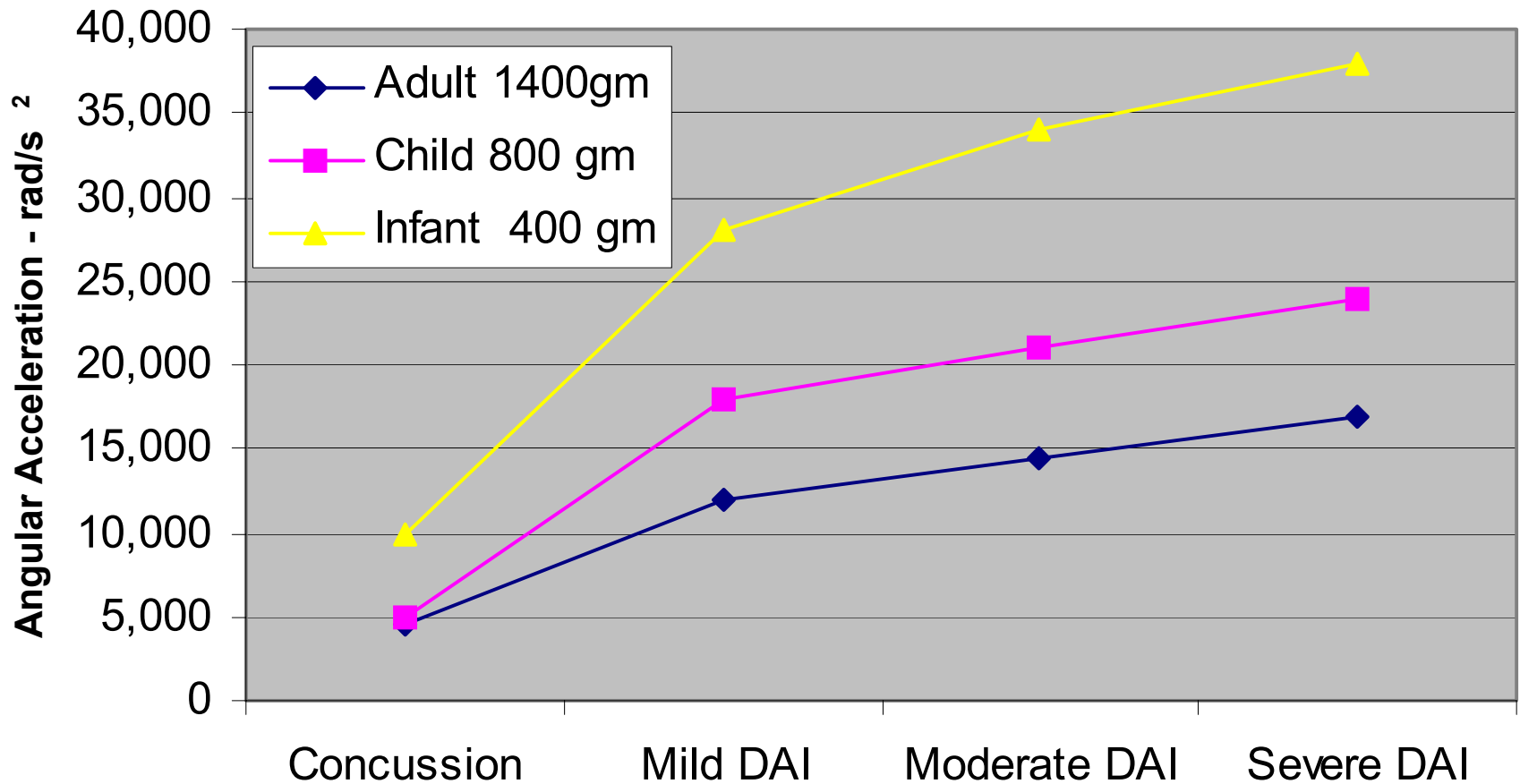
Directional Dependence of Diffuse Brain Injury

Experimental Subjects with comparable acceleration input

DAI GRADE	SAGITTAL	HORIZONTAL	CORONAL
0	4	0	0
1	5	1	0
2	0	9	1
3	0	0	8



Inertial Tolerances



Relation of Tolerances to Adjectival Descriptors of Diffuse Brain Injury

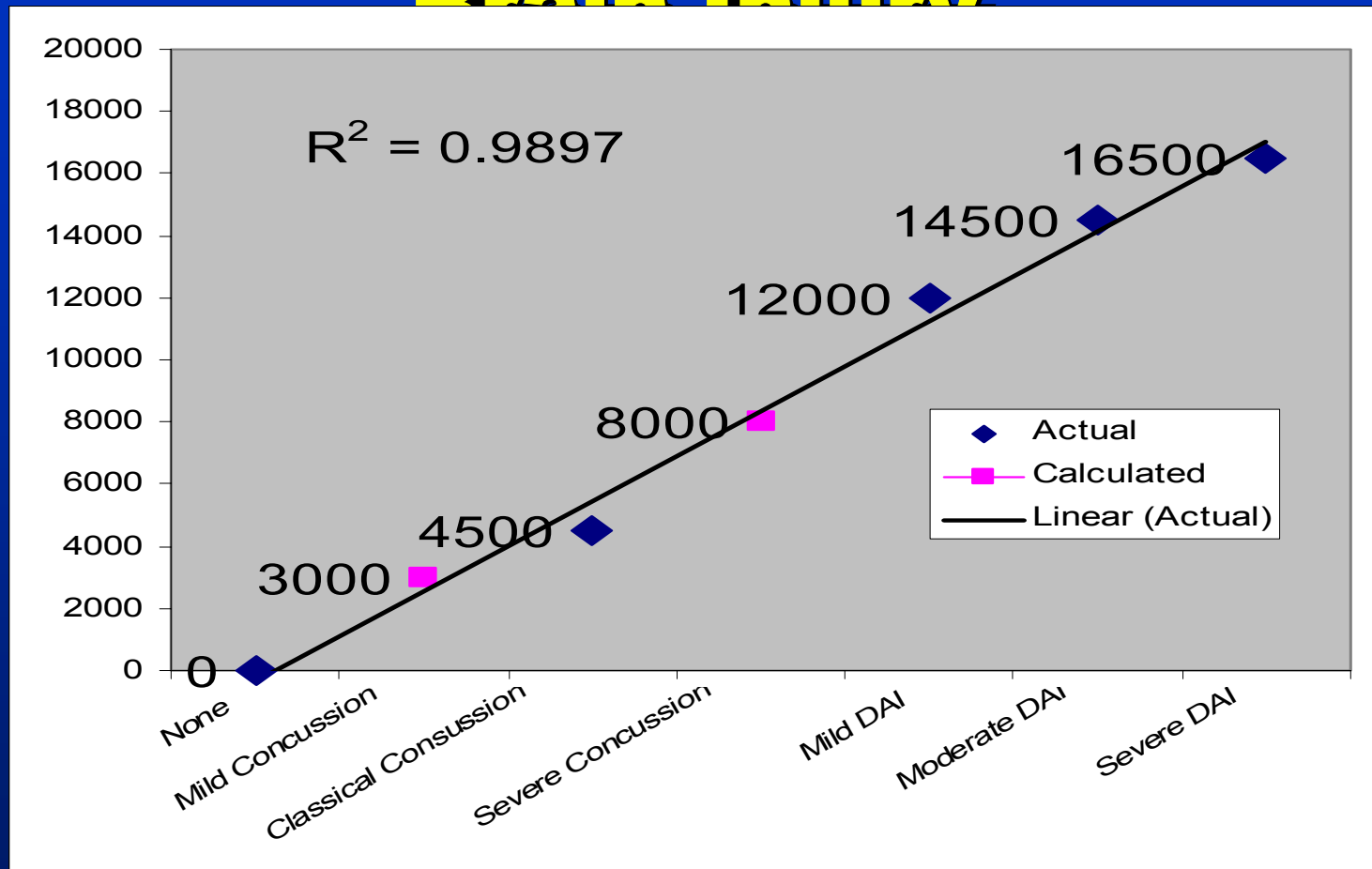


Fig 2. Results of using scaled tolerances values from Margulies to equivalent adjectival descriptors (actual = Margulies values) and interpolating values for mild and severe concussion (calculated)

Relation of Diffuse Brain Injury Tolerances to AIS

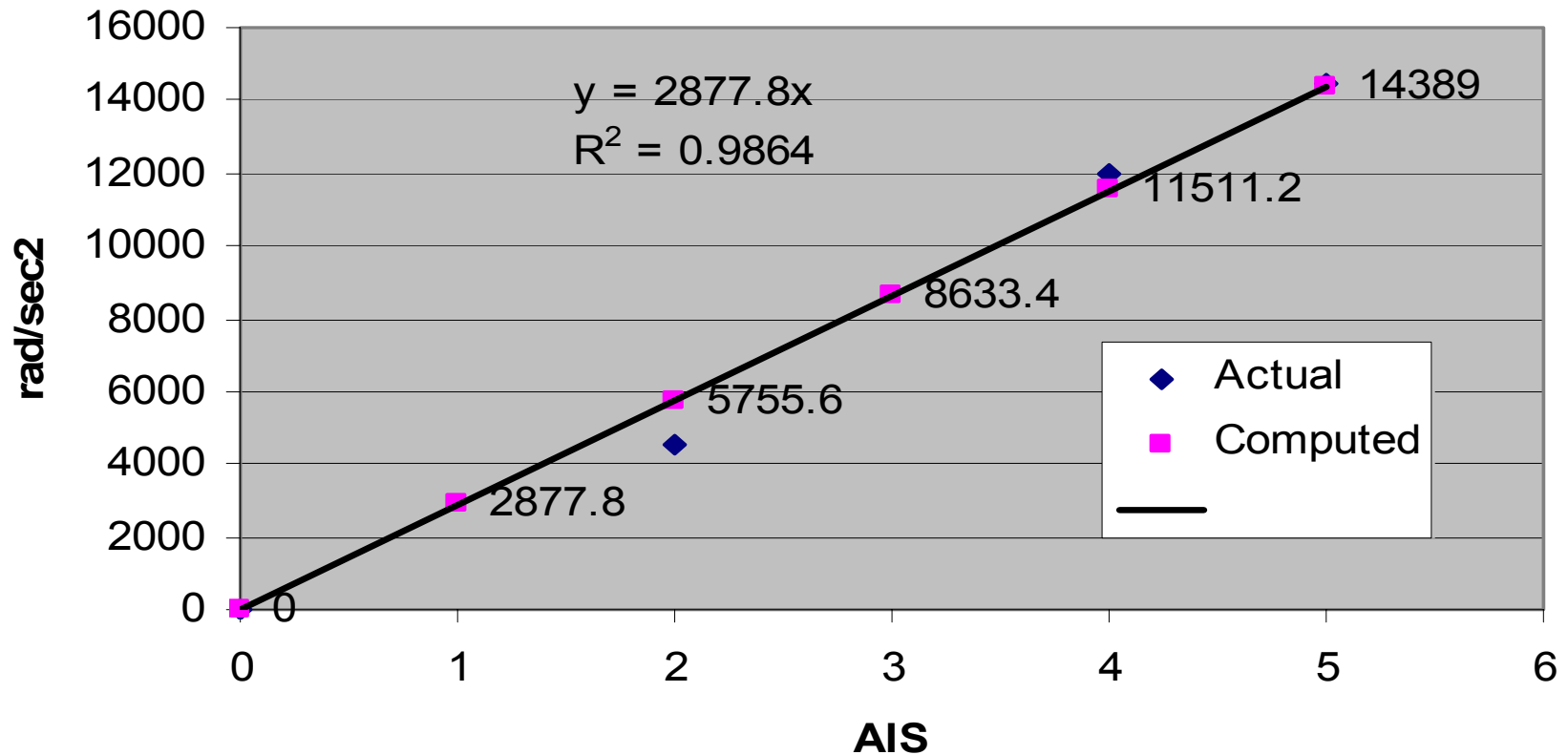


Fig 1. Results of using scaled tolerances values from Margulies to equivalent AIS values (actual; AIS = 0, 2,4,5) and interpolating values for AIS values 1,3 (computed)

Concussion Symptom Inventory (CSI)

Randolph, Barr, McCrea, Millis, Guskiewicz, Hammeke, Kelly, 2005

Symptom	Absent	Present
HEADACHE	0	0
NAUSEA	0	1
BALANCE PROBLEMS/DIZZINESS	0	1
FATIGUE	0	1
DROWSINESS	0	1
FEELING LIKE "IN A FOG"	0	1
DIFFICULTY CONCENTRATING	0	1
DIFFICULTY REMEMBERING	0	1
SENSITIVITY TO LIGHT	0	1
SENSITIVITY TO NOISE	0	1
BLURRED VISION	0	1
FEELING SLOWED DOWN	0	1
TOTAL		_____

Grades of Concussion

		Grade 1	Grade 2	Grade 3
JAMA 1997	LOC	-	-	+
	Sx	<15 min	>15 min	
Santus 1997	LOC	-	<5min	>5min
	PTA	<1hr	1-24hr	>24hr
JAMA 1991	LOC	-	-	+
	Confusion	+	+	+
	Amnesia	-	+	+
JAMA 1985	LOC	-	few min	+
	amnesia	PTA	PTA or RGA	PTA+RGA

Results

● Production of risk curves

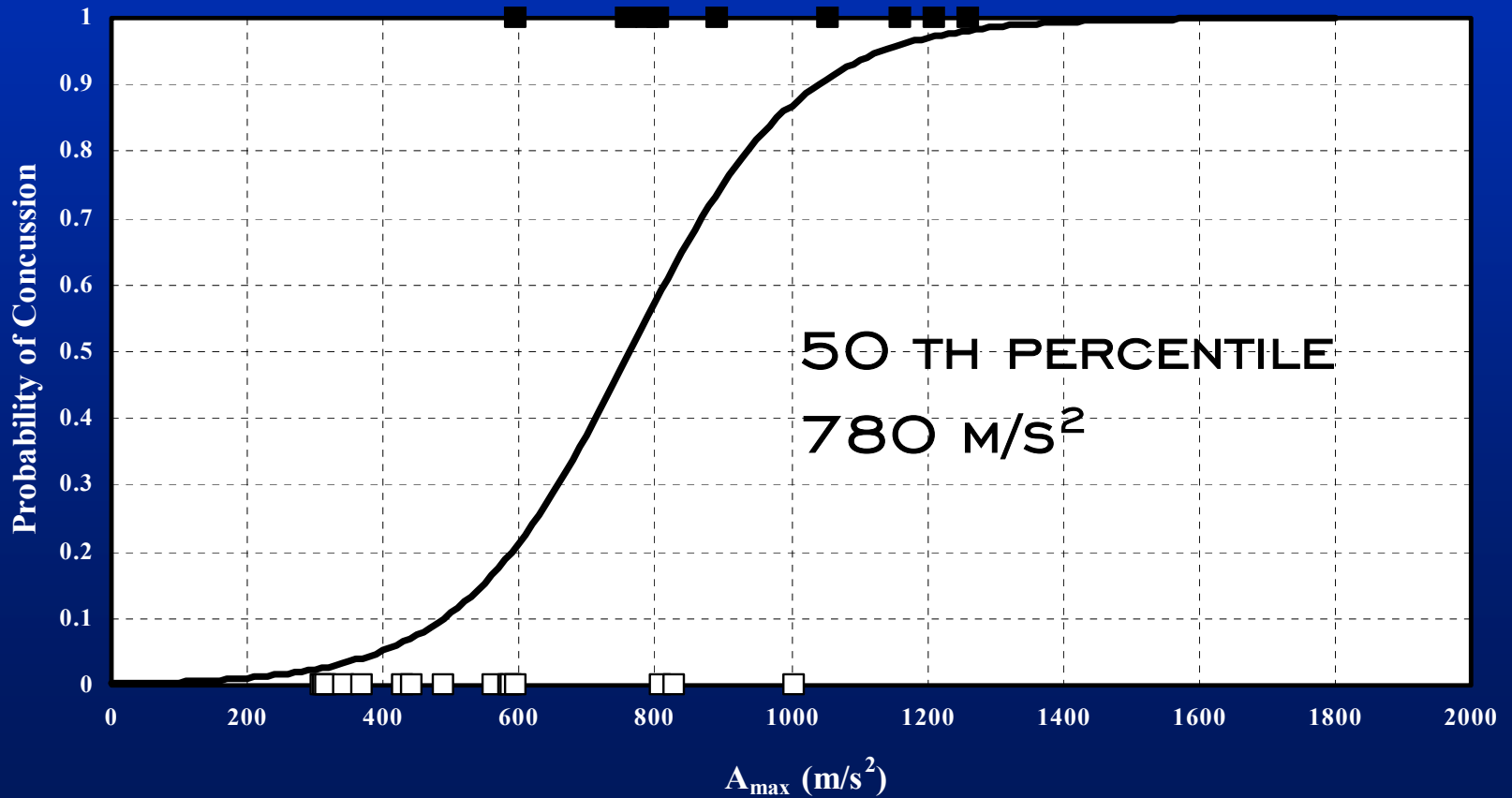
- Each curve represents the probability of Mild Traumatic Brain Injury being associated with a specific value of injury measure

● Results of Logistic Regression Analyses

	a_m	α_m	SI	HIC ₁₅	GAMBIT	HIP
Significance P-value	0.011	0.029	0.024	0.020	0.013	0.008
-2LLR	18.059	20.676	18.195	19.347	18.031	14.826

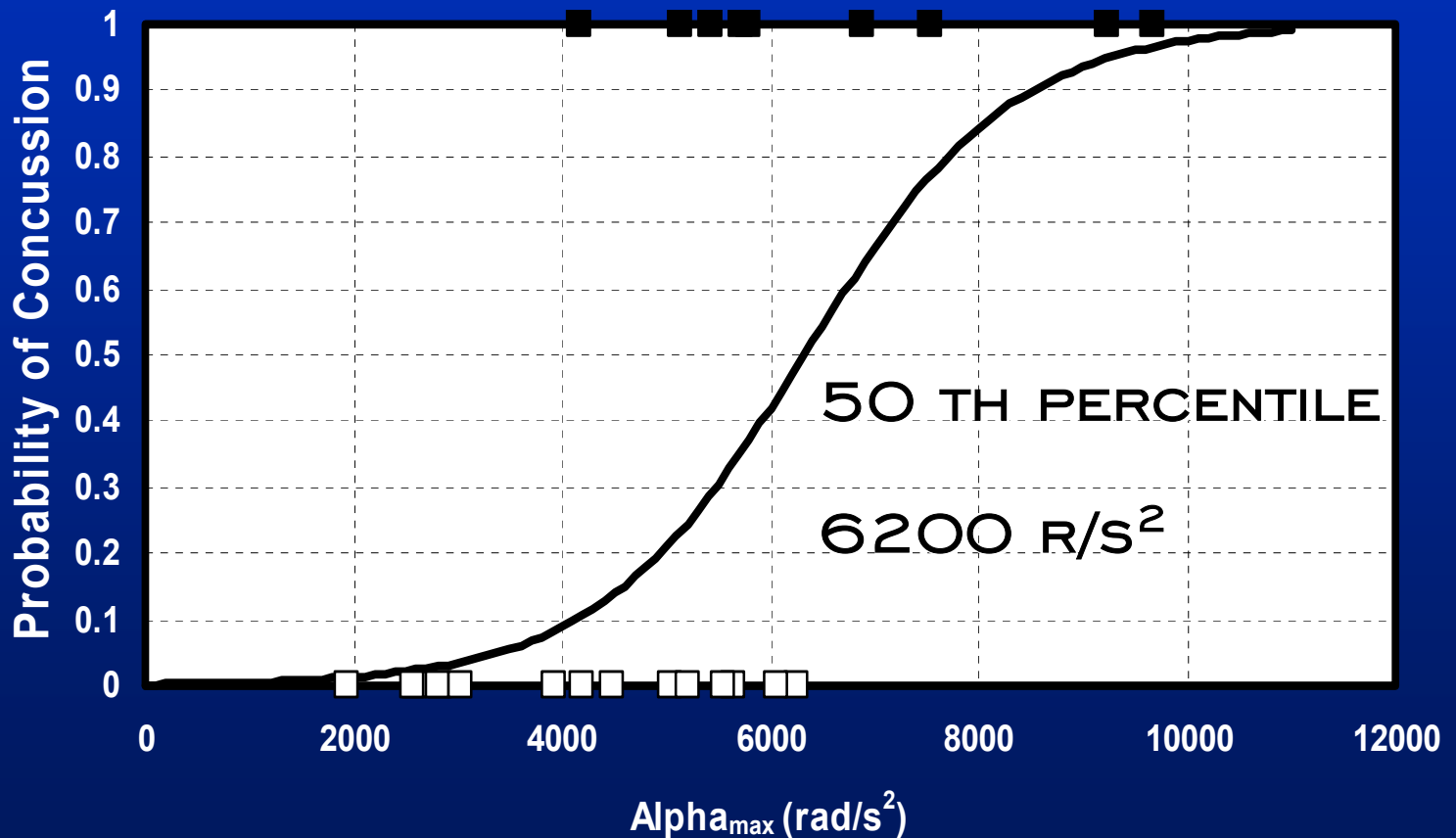
Probability of MTBI: A_{max}

(n=24)

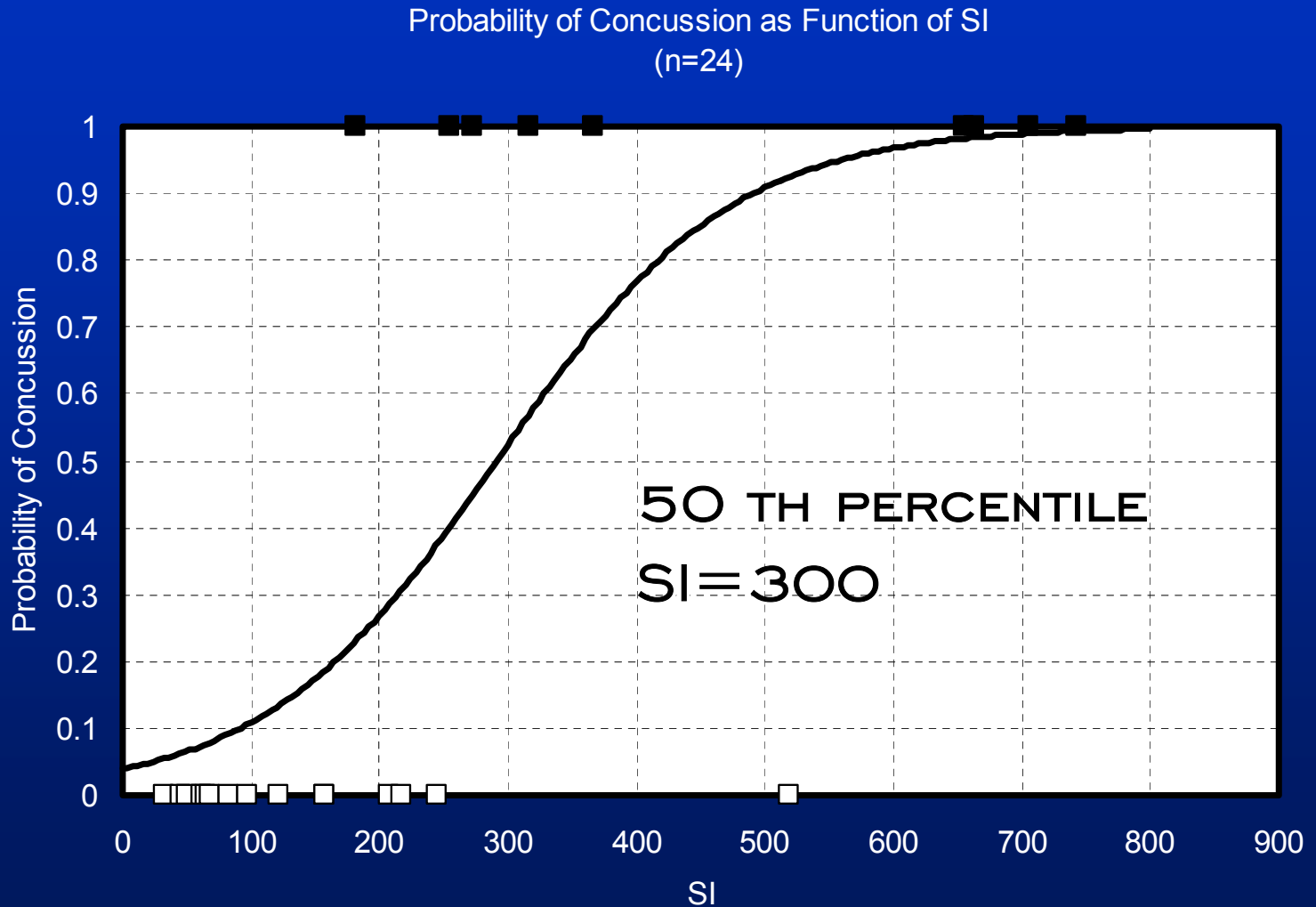


Probability of MTBI: α_{max}

(n=24)



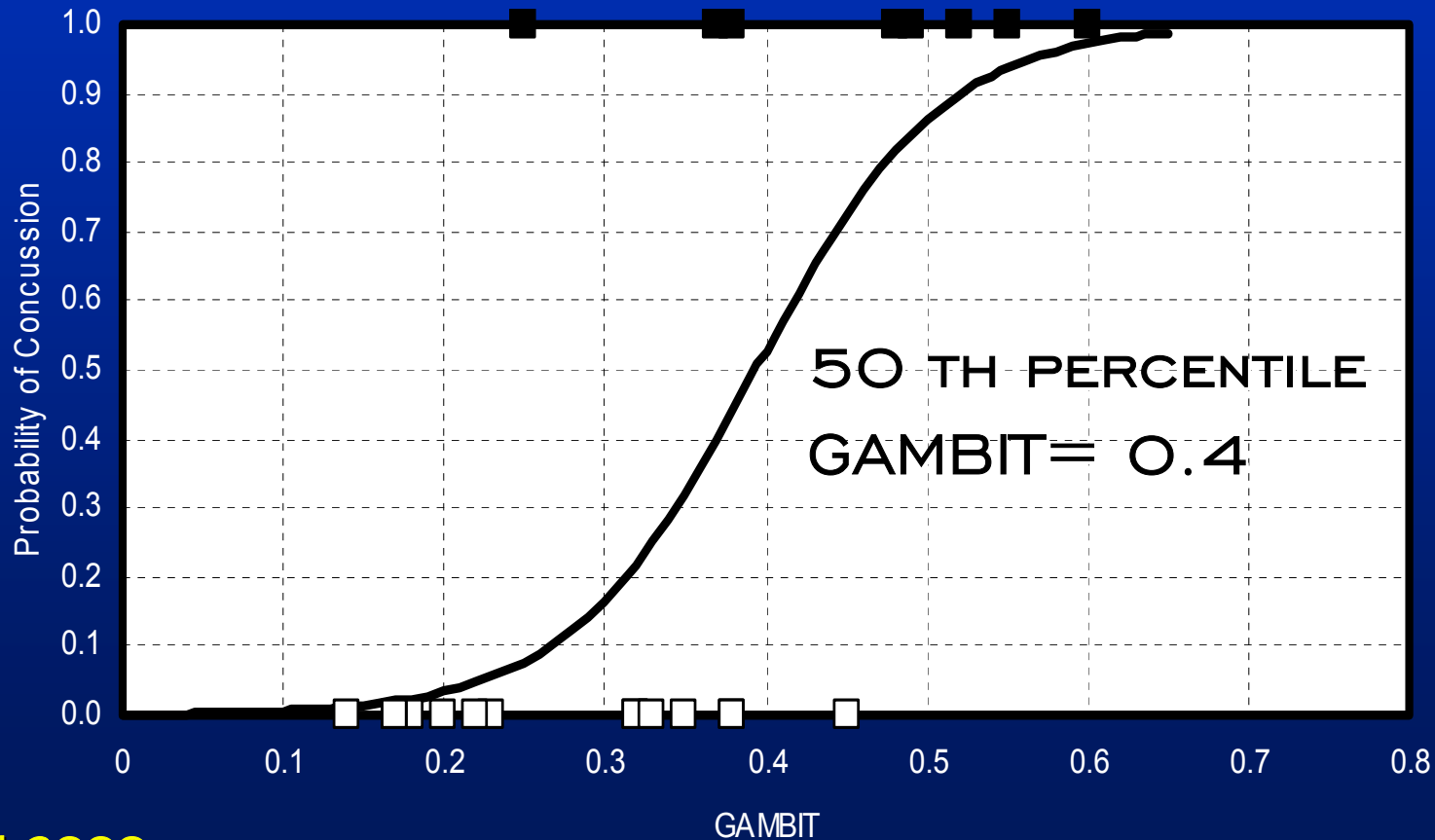
Probability of MTBI: SI



Probability of MTBI: GAMBIT

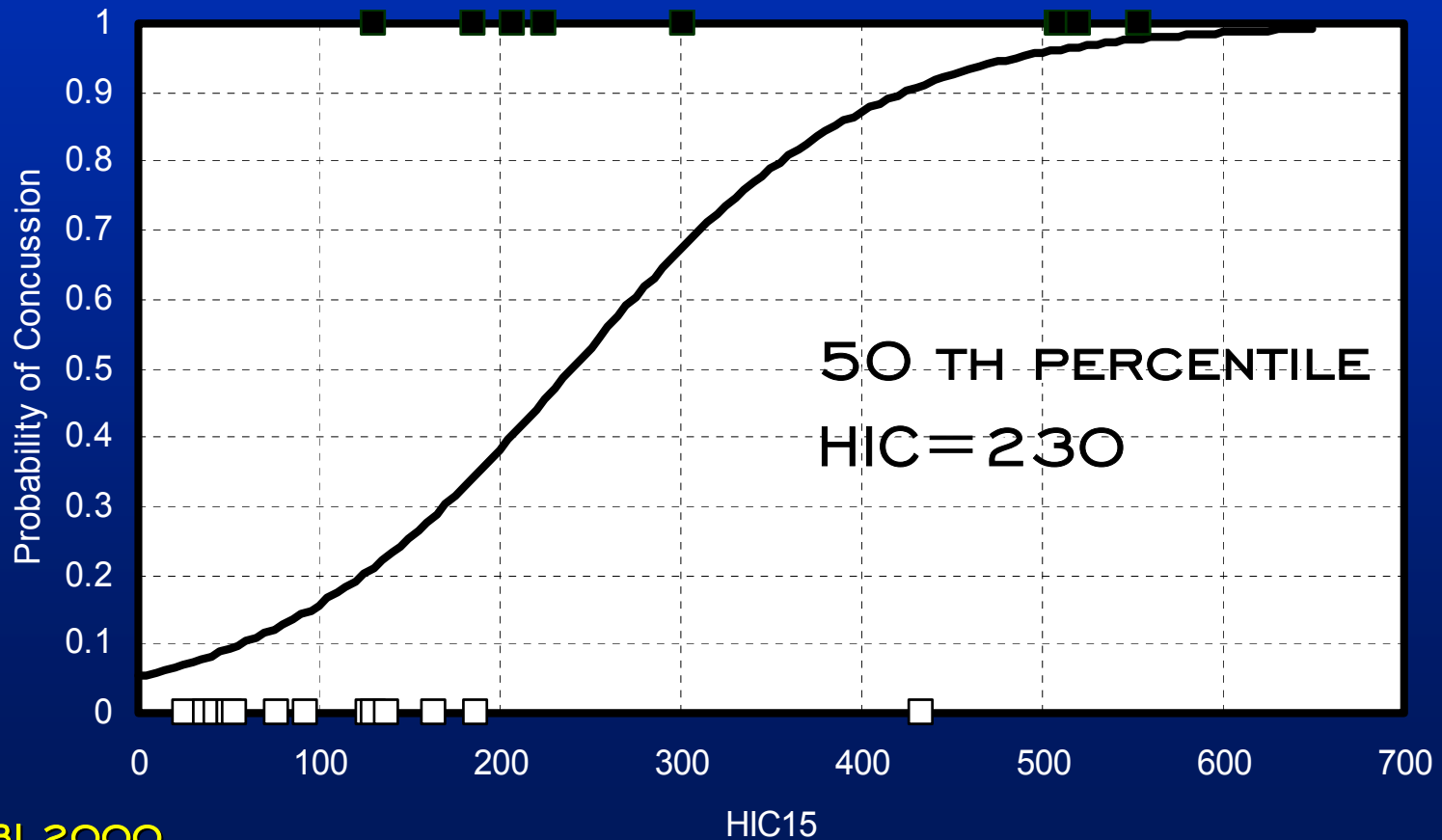
Probability of Concussion as Function of GAMBIT

(n=24)



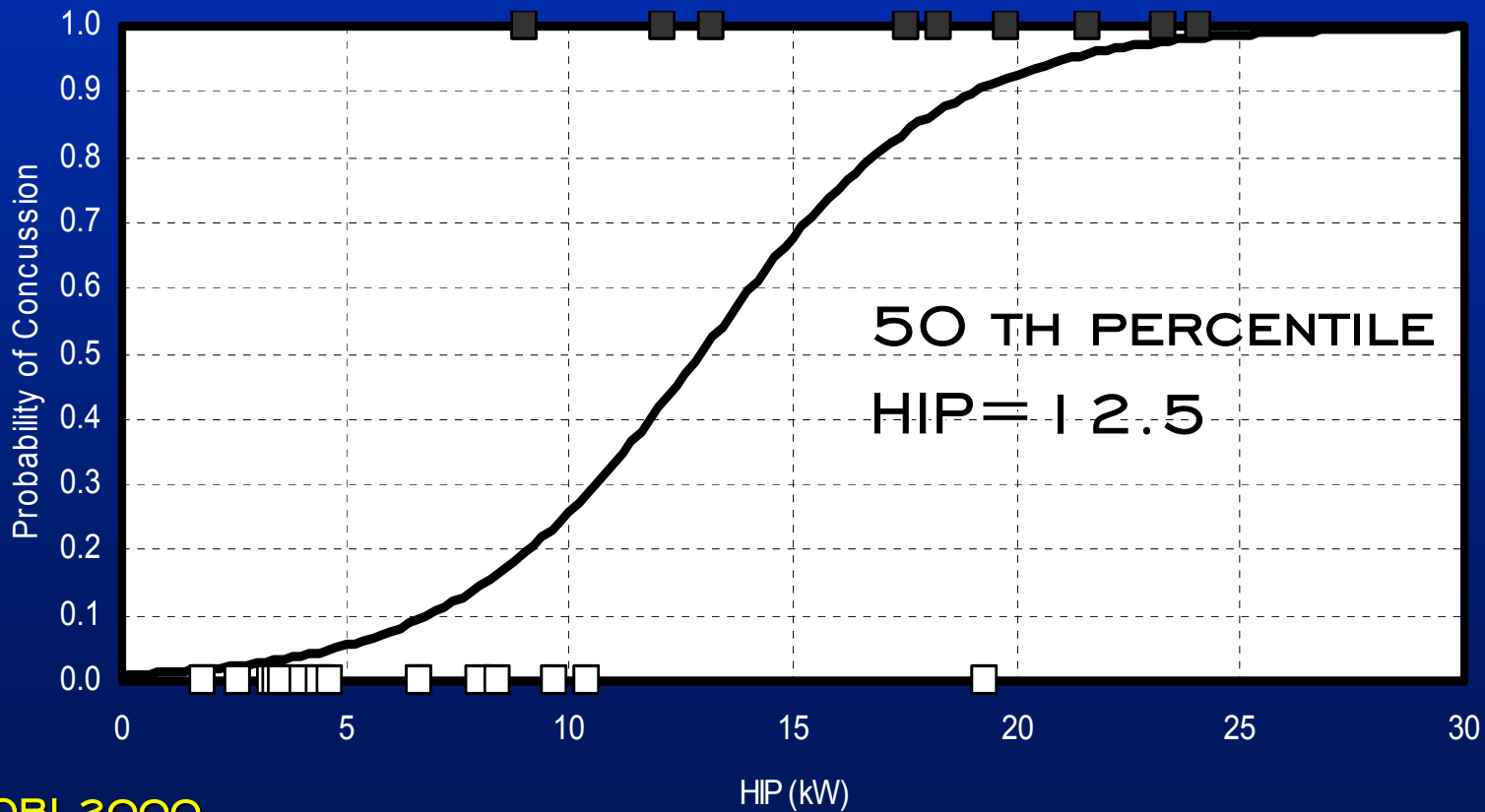
Probability of MTBI: HIC₁₅

Probability of Concussion as Function of HIC15
(n=24)



Probability of MTBI: HIP

Probability of Concussion as Function of HIP
(n=24)



Tolerances for mTBI: King 2003

Predictor Variable Threshold Values for Likelihood of MTBI

	25%	50%	75%
$A_r \text{ max (m/s}^2\text{)}$	559	778	965
$R_r \text{ max (rad/s}^2\text{)}$	4384	5757	7130
HIC_{15}	136	235	333
ε_{max}	0.25	0.37	0.49
$d\varepsilon/dt_{\text{max}} \text{ (s}^{-1}\text{)}$	46	60	79
$\varepsilon \bullet d\varepsilon/dt_{\text{max}} \text{ (s}^{-1}\text{)}$	14	20	25

King: 2003

- **At least for MTBI, the best predictor for injury is neither linear nor angular acceleration**
- **It is the product of strain and strain rate**
- **This may be controversial but it is biomechanically reasonable because brain response governs injury, not the input**

What are we trying to prevent?

- **Which TBI are “acceptable?”**
- **Which TBI are unacceptable?**
- **Are these the same for all circumstances?**
- **Given the advances in the last 50 years. Don't we have to lower the bar and prevent more TBI?**

TOTAL PROTECTION FROM TBI





Cheesehead saves day, life of plane passenger

STEVENS POINT (AP) — A Green Bay Packers fan who survived a plane crash credits his yellow foam rubber cheesehead for giving him another chance to cheer on the home team.

"It was in my lap, because I was using it as pillow when I was snoozing an hour before," Frank Emmert, 36, said Tuesday. "You know when you crash in the big ones, they tell you to cover your head with a pillow."

Emmert was flying back home to Superior on Sunday after spending a week in Ohio following the Nov. 19 Packers-Browns game. His traveling companion, Baron Bryan, 25, also from Superior, was the pilot.

Ice on the wings may have caused the small plane to crash near the Stevens Point Municipal Airport, Emmert said.

"We went straight down," Emmert said.

As the plane dropped, Emmert grabbed the wedge-shaped cheesehead and covered his head. Once on the ground, he discovered Bryan had suffered a head injury. Emmert kicked the door open.

"That's when I found out I had a broken ankle," he said.

Emmert won't have to buy a new cheesehead to replace the one he used in the crash.

"The gentleman that owns the company sent cheeseheads to my family and my boys," Emmert said.