



## Occupant loading in Pole Side Impact

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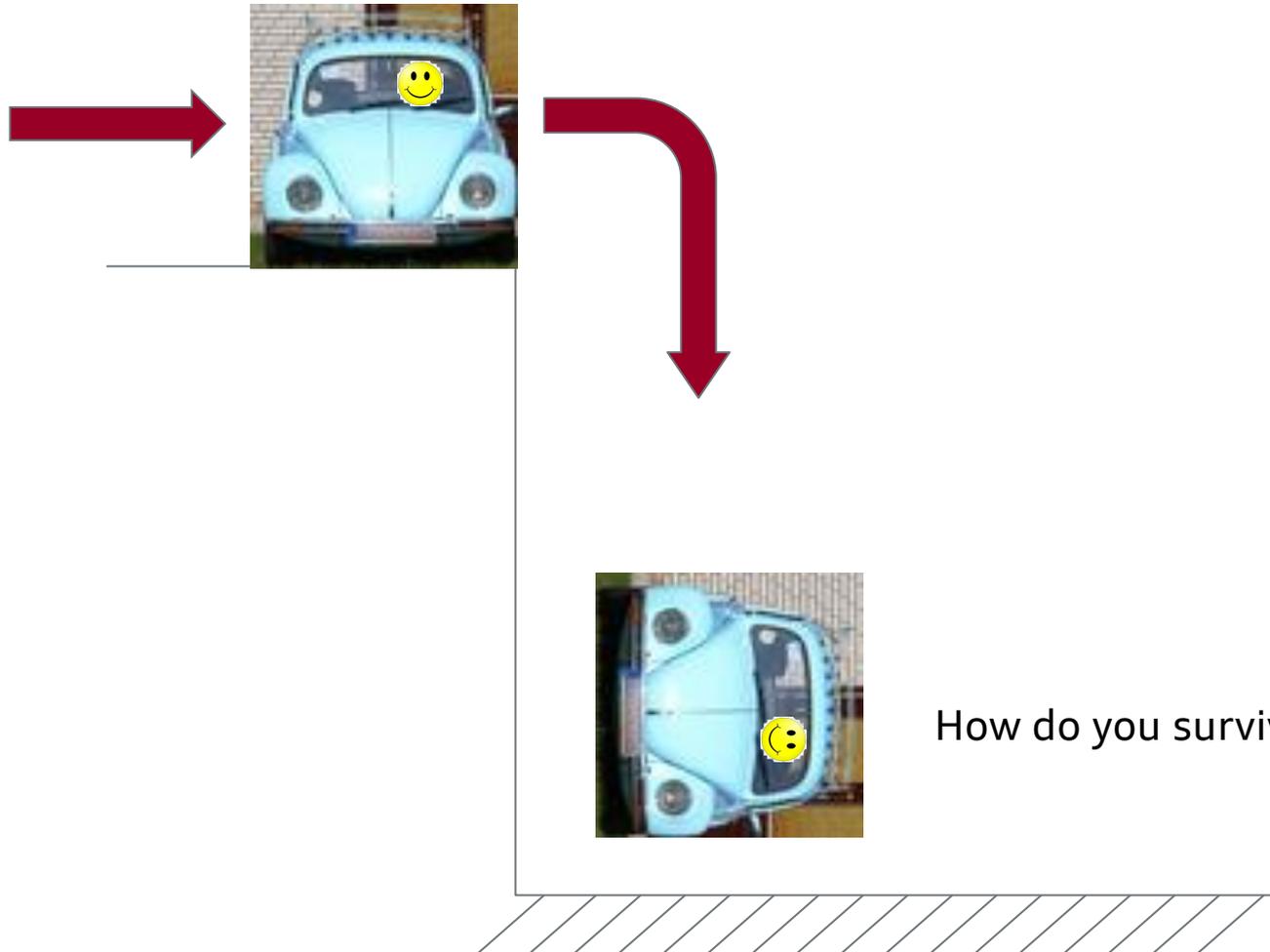
# Occupant loading in Pole Side Impact

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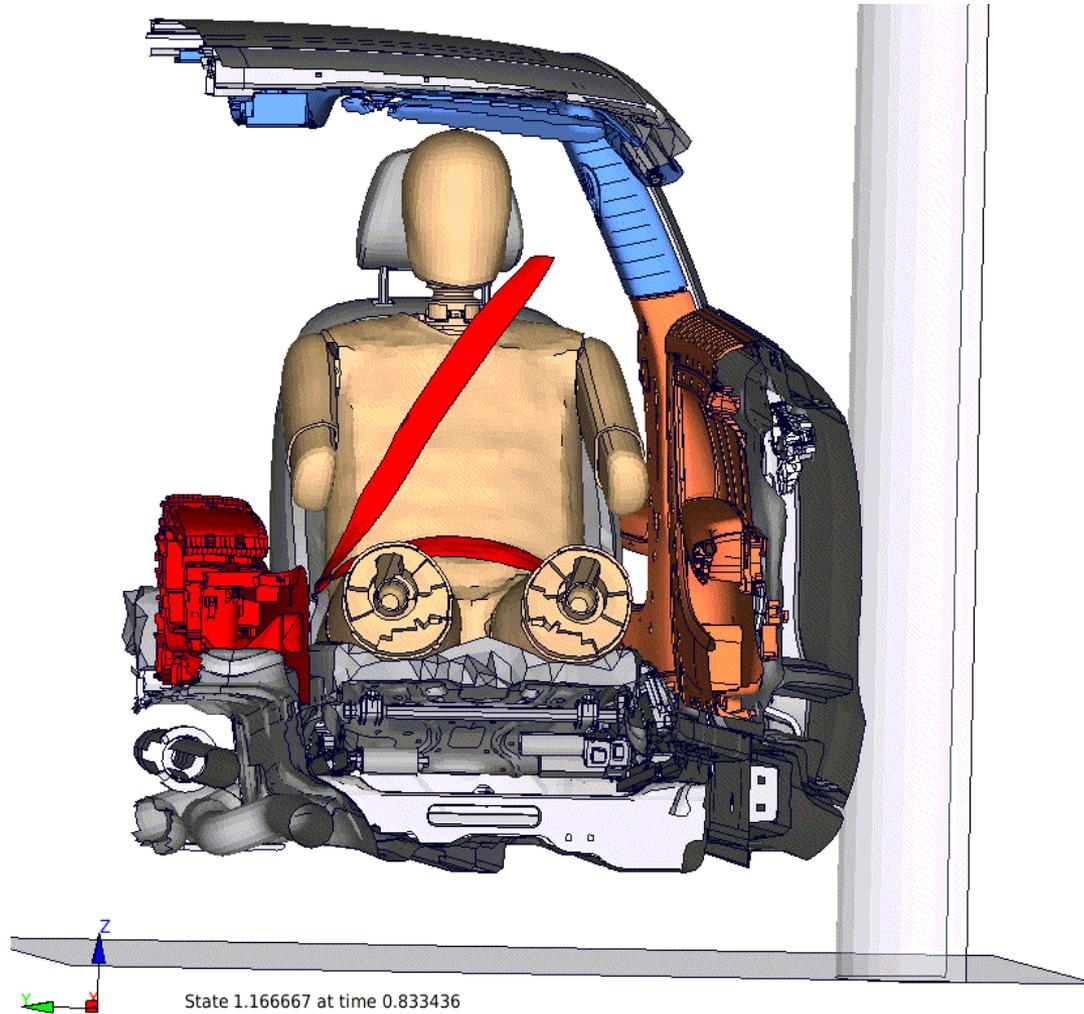
# Occupant loading in Pole Side Impact

Pole Side Impact - to keep it simple:



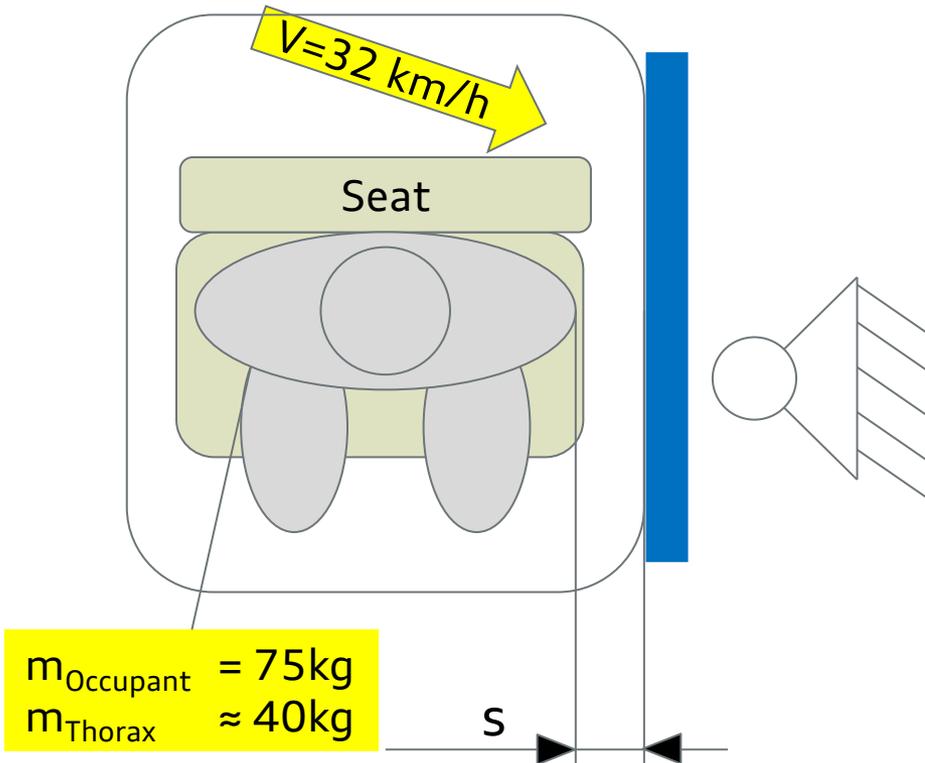
How do you survive a Pole Side Impact?

# Occupant loading in Pole Side Impact



# Occupant loading in Pole Side Impact

Background to the physics:



Energy of occupant's thorax :

$$E_{\text{kinematic1}} = \frac{1}{2} m \cdot v^2 = \frac{1}{2} \cdot 40 \text{ kg} \cdot (8,9 \text{ m/s})^2$$

Before crash:

$$E_{\text{kinematic1}} = 1584 \text{ J} = 1584 \text{ Nm}$$

After Crash:

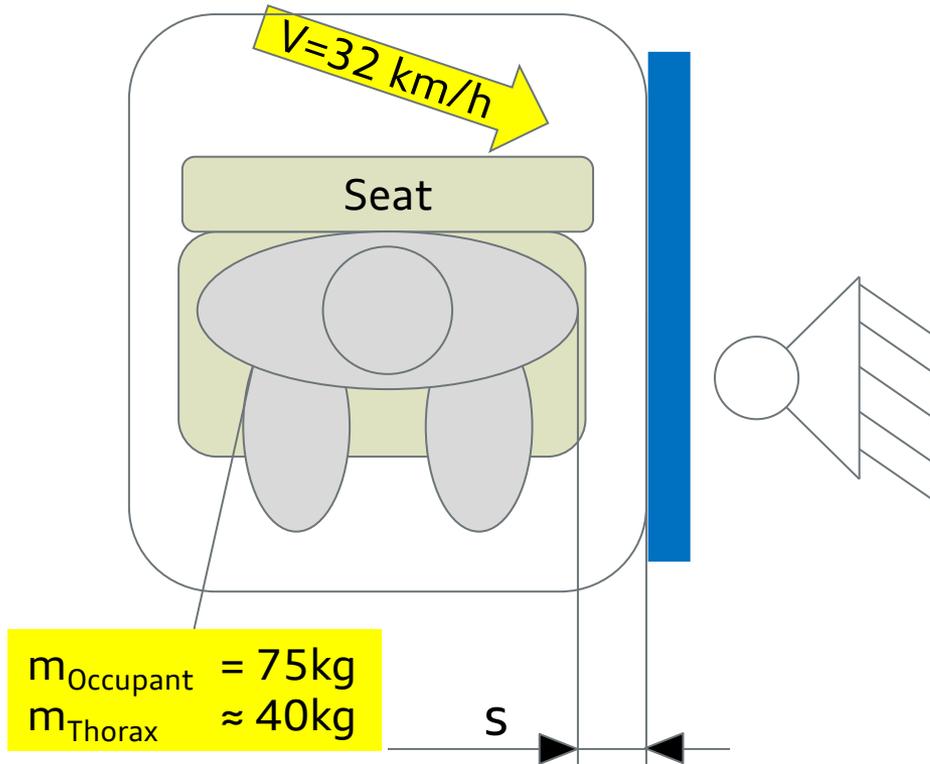
$$E_{\text{kinematic2}} = 0 \text{ Nm}$$

Restraint System:

$$W_{\text{RS}} = E_{\text{kin1}} - E_{\text{kin2}} = E_{\text{kin1}} = F \cdot s = 1584 \text{ Nm}$$

# Occupant loading in Pole Side Impact

Background to the physics:



Available space,  $s$ :

$$s \approx 100 \text{ mm}$$

Estimated average force applied to the thorax:

$$F = W_{\text{RS}} / s$$

$$F = 1584 \text{ Nm} / 0,1\text{m}$$

$$F = 15840\text{N} \approx 16 \text{ kN}$$

(Including seat friction, belt forces ...)

# Occupant loading in Pole Side Impact

What we can do for occupant protection and energy absorption:

- ▶ Use as much space as possible to maximize side impact restraint performance
- ▶ Try to keep the load at a constant level
- ▶ Avoid concentrated loads

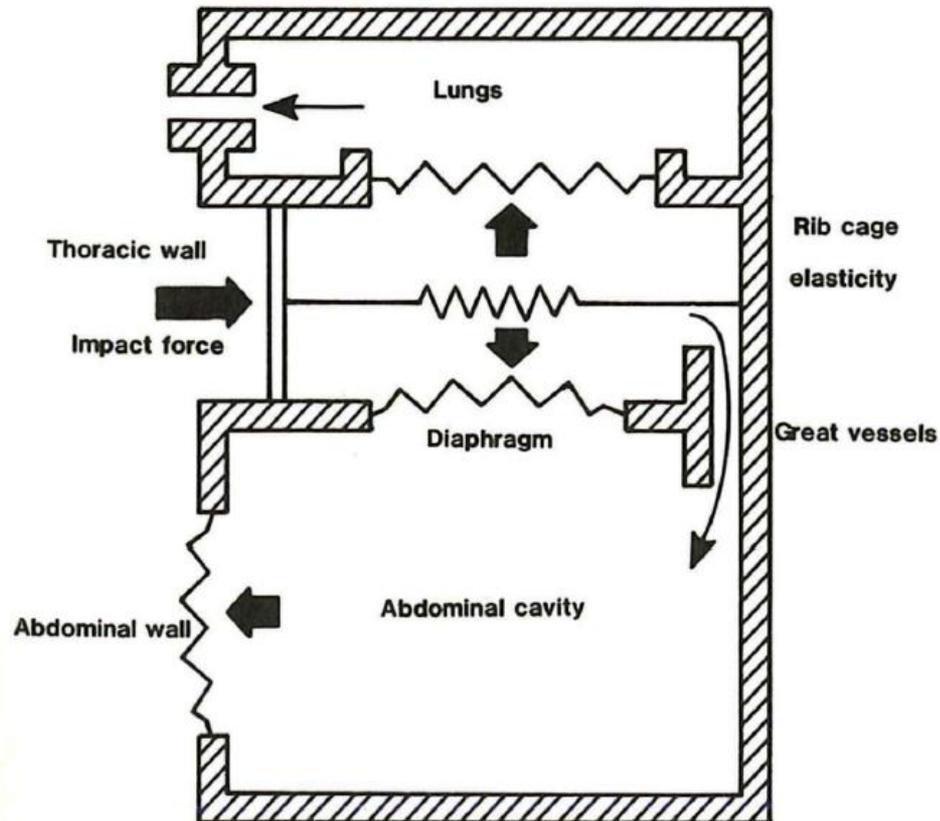
However:

**In a severe pole crash, loading of the occupant is inevitable**

→ To handle these loads we need to

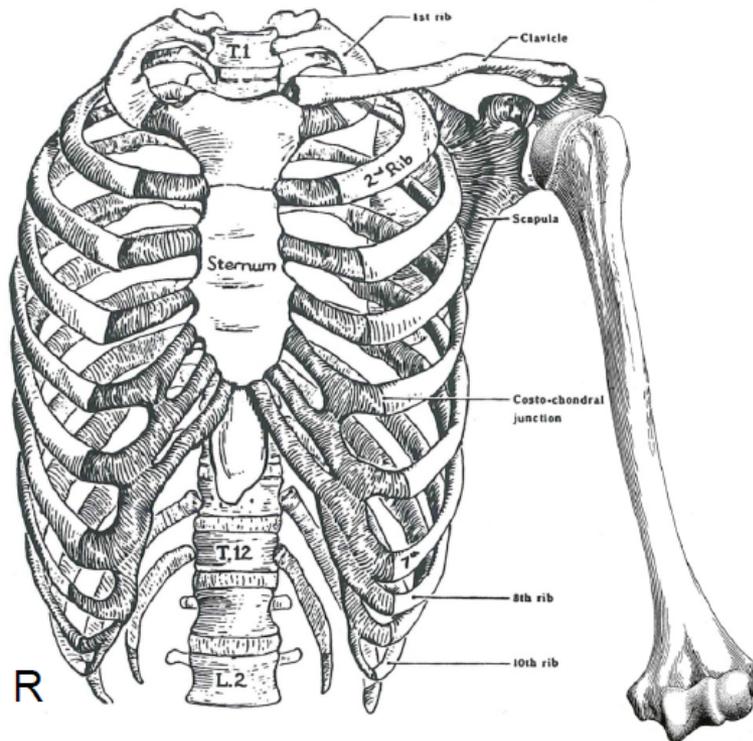
- ▶ **direct the loads** towards the body regions with greater ability to take these loads
- ▶ **limit forces** on sensitive body areas.

## Simplified Torso Model

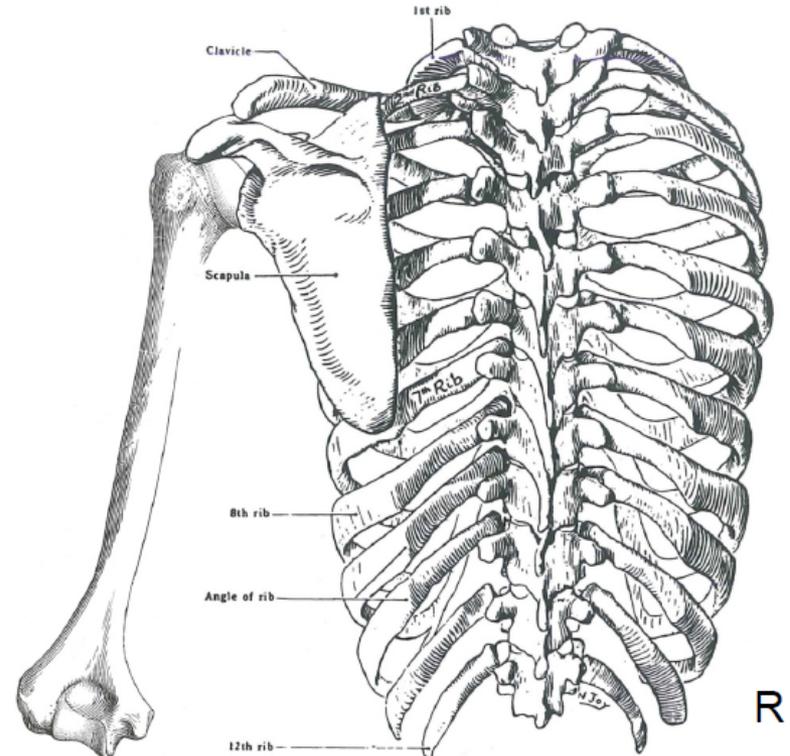


Jean-Pierre Verriest  
Thorax and Upper Abdomen: Kinematics, Tolerance Levels and Injury Criteria.  
In: Bertil Aldman, Andre Chapon  
The Biomechanics of Trauma, 1984, 251-275. Figure 2.

# Anatomical Situation: The bony Thorax



front view

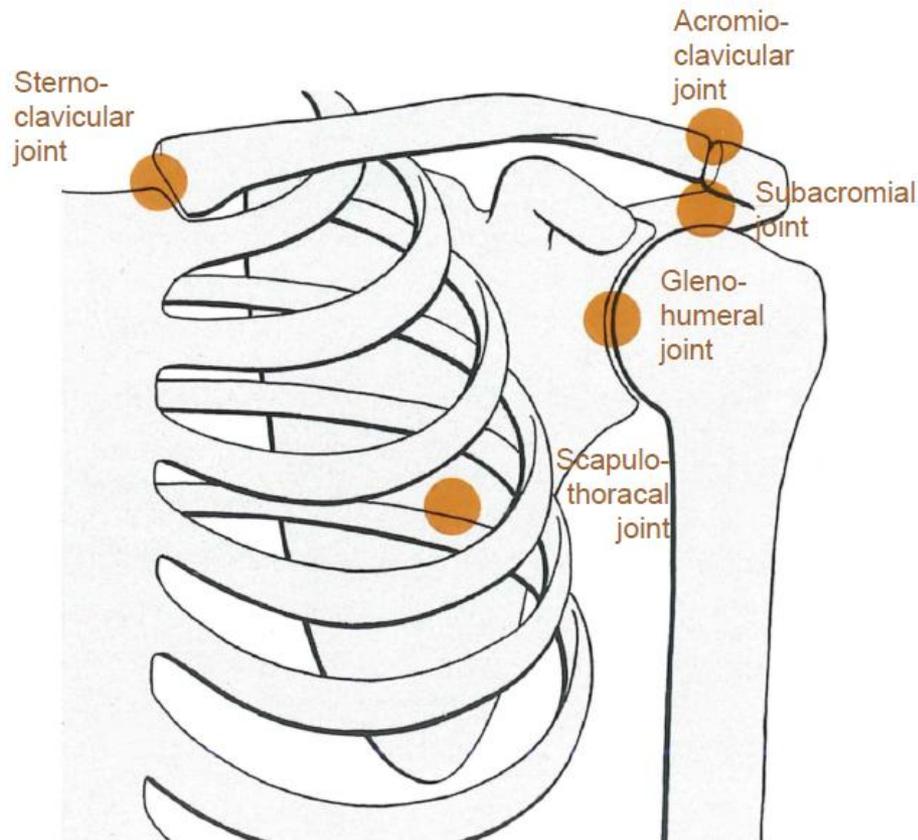


rear view

(scaled and arms added )  
 John M. Cavanaugh  
 Biomechanics of Thoracic Trauma  
 In: Alan M. Nahum, John W. Melvin  
 Accidental Injury, 2nd edition, 2002, Chapter 16, Figure 16.1, rescaled.



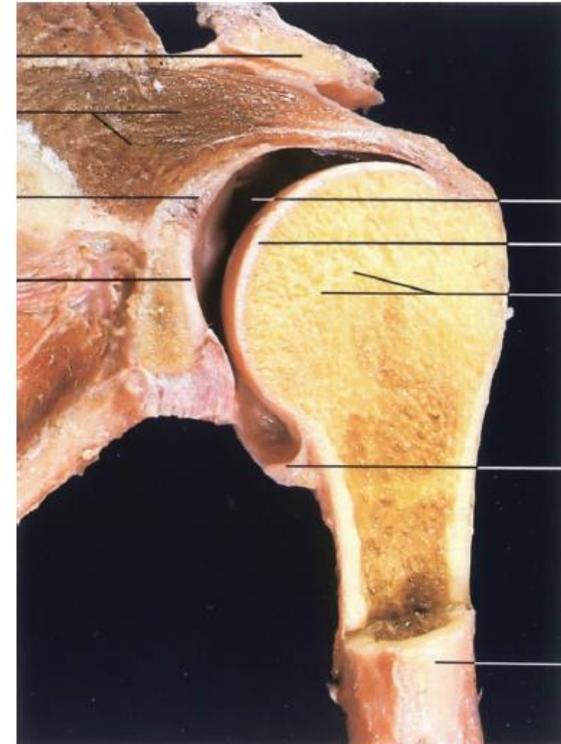
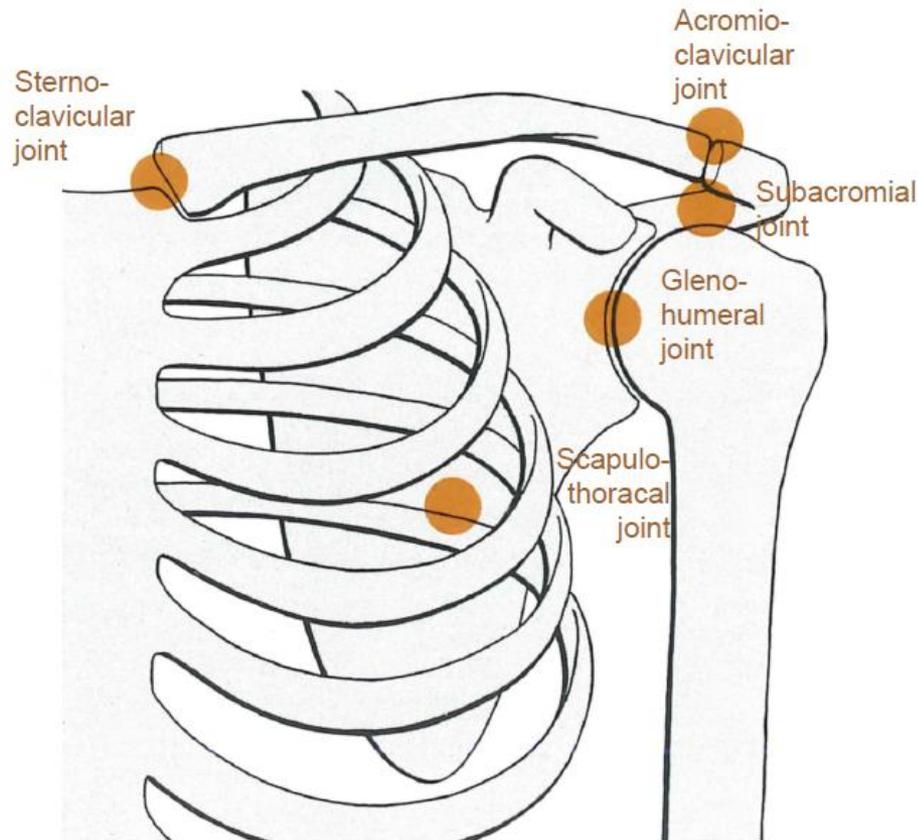
## The 5 joints of the shoulder



1. Glenohumeral joint
2. 'Subacromial joint'
3. Sternoclavicular joint
4. Acromioclavicular joint
5. 'Scapulothoracal joint'

W. Keyl  
Schultergürtel  
In: Michael Jäger, Carl Joachim Wirth  
Praxis der Orthopädie, 1986, Abbildung 1, 8, 28.

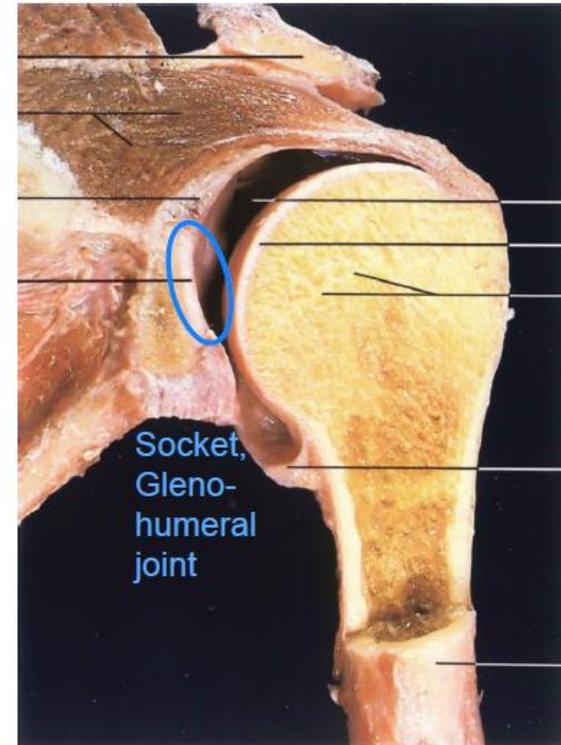
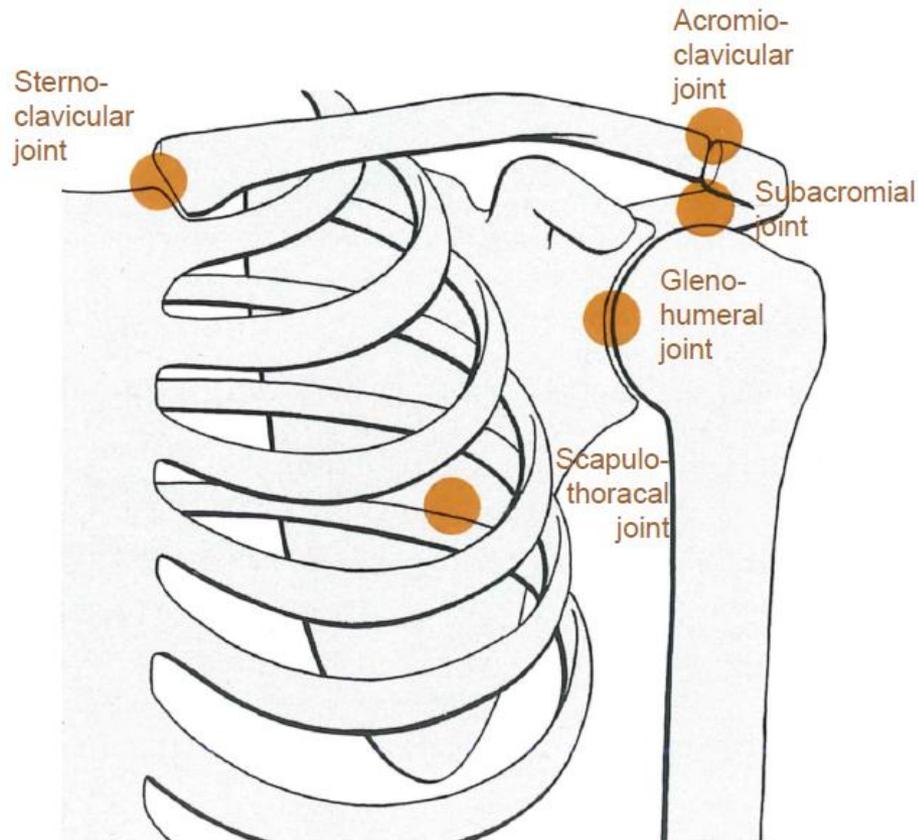
## The 5 joints of the shoulder



Johannes W. Rohen, Chihiro Yokochi  
Anatomie des Menschen  
Schattauer, 1993, Seite 356

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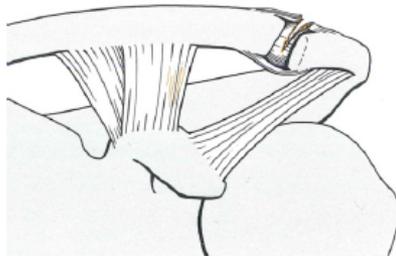
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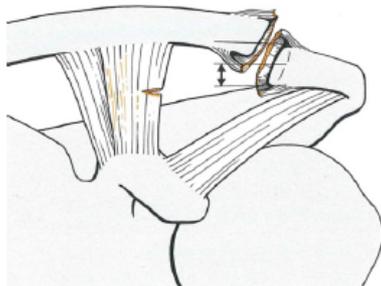


## Acromioclavicular joint injuries

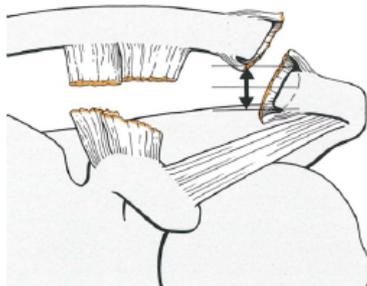
The typical injuries of the side impact → Shearing force on ligaments



Partial rupture of the AC ligament (Tossy I)  
→ No functional deficiencies



Complete rupture of the AC ligament, partial rupture of the CC ligament (Tossy II)  
→ Clavicle dislocated upwards (half its width)

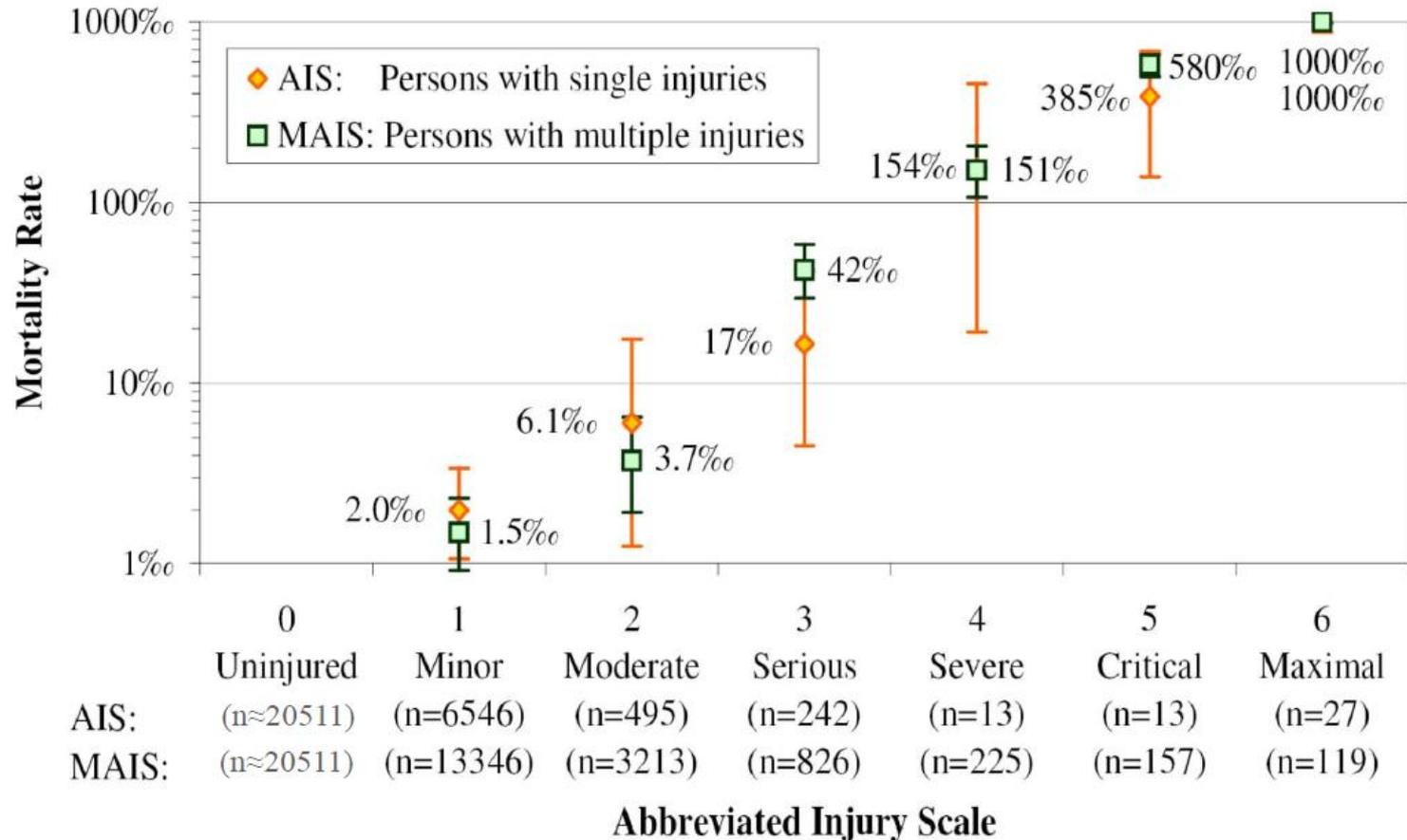


Complete rupture of the AC and CC ligaments (Tossy III)  
→ Clavicle dislocates upwards

W. Keyl  
Schultergürtel  
In: Michael Jäger, Carl Joachim Wirth  
Praxis der Orthopädie, 1986, Abbildung 1, 8, 28.



## AIS98 vs. Mortality Rate



Sean O'Brien, 2010, Dissertation, Section 3  
Measurement and Assessment of Passenger Vehicle Compatibility in Front and Side Collisions.



# Injury Scaling using the Abbreviated Injury Scale (AIS)

## Thorax

Code	Rib Fractures, number of		
	AIS 1976	AIS 90/98	AIS 2008
1		1	
2	1	2-3	2
3	2+	4+	3+
			3-5 + flail
4	1+ + flail	bilateral 4+ flail	5+ + flail
5		bilateral flail	
6	crushed chest		

Code	Soft Tissue Injuries		
	AIS 1976	AIS 90/98	AIS 2008
1			heart contusion, minor
2		distal bronchus laceration	
3	lung contusion	lung contusion, unilateral	lung contusion, unilateral, major
		heart contusion, minor	
	hemothorax		
4		pneumothorax	
		lung contusion, bilateral	lung contusion, bilateral, major
		lung laceration, bilateral	lung laceration, unilateral, major
	heart contusion	heart contusion, major	
5			pneumothorax, major
	aortic laceration		lung laceration bilateral, major
			pneumothorax, tension

Stand: 20.06.2012

Dr. Mirko Junge, K-EFFS/G

## Shoulder

Code	Shoulder		
	AIS 1976	AIS 90/98	AIS 2008
1			
2		GH/AC/SC dislocation	
		Humerus head fracture	
3	Humerus head fracture	Humerus head fracture (open)	
		crush (humerus head)	
		crush (arm)	
4	crush (arm)		crush (shoulder)

# Occupant loading in Pole Side Impact

## Conclusions

- ▶ In a severe pole crash, loading of the occupant is inevitable.
- ▶ In order to protect the occupants well in a PSI the goal is to direct the loads towards the body regions with greater ability to take these loads while limiting forces on sensitive body areas.
- ▶ The sensitive thorax area is left at much higher risk by lowering the shoulder forces.
- ▶ A flail chest has a real mortality rate associated with it, whereas the repositioning of shoulder joint dislocations are routine procedures as is the surgical reconstruction of the humerus head.
- ▶ To give shoulder injury risk reduction a higher priority than sensitive body regions, such as the head and thorax, seems to be a risky approach.

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Thank you!

Any questions?