The Injured Spine

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San Francisco, Ca

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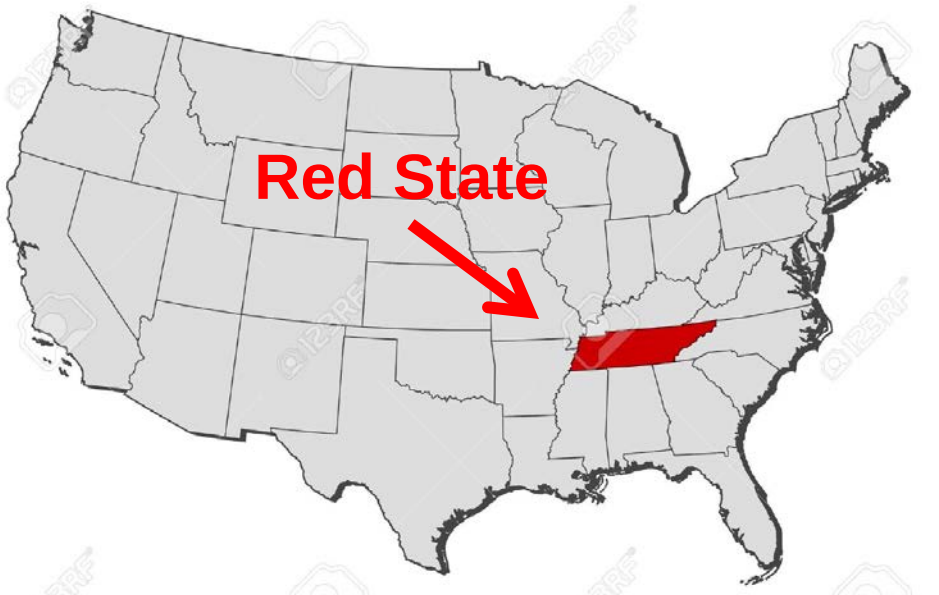
R. Trigg McClellan, MD



R. Trigg McClellan, MD

Clinical Professor Orthopaedic Surgery

Vanderbilt University	1981	MD
Vanderbilt University	1981 - 1983	General Surgery
University of Michigan	1983 - 1986	Orthopaedic Surgery
UCSF	1986 - 1987	Fellow, Orthopaedic Trauma
San Francisco General Hosp.	1986 - 1987	Fellow, Orthopaedic Trauma
Kerlan-Jobe Clinic, Los Angeles	1997 - 1998	Fellow, Spine Surgery

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FIND A PASSION AND GO TO WORK EVERYDAY

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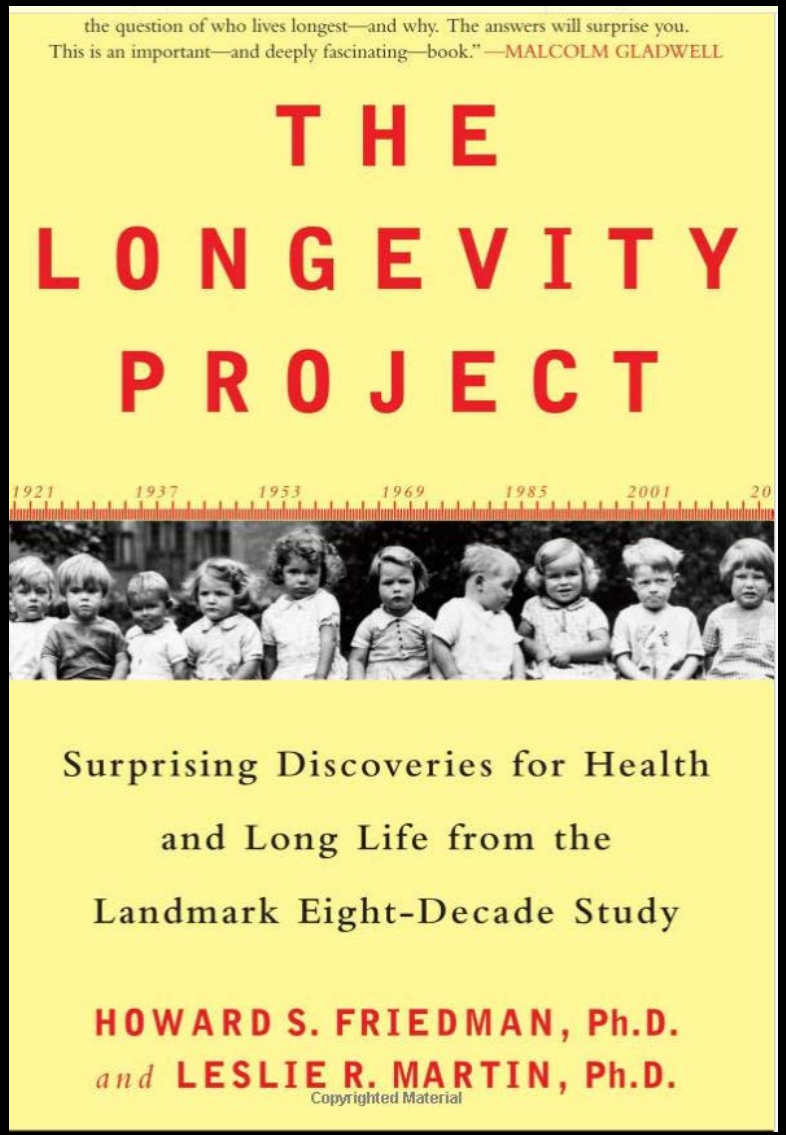
How to Live a Long Life



In fact, many of those who worked the hardest turned out to live the longest.

According to *The Longevity Project*, actually achieving your lifelong dreams doesn't matter. *Pursuing* those dreams is what counts:

"We did not find that precisely living out your dreams matters much for your health. It was not the happiest or the most relaxed older participants who lived the longest. It was those who were most engaged in pursuing their goals.

"Those who were the most successful were the ones least likely to die at any given age. **In fact, those men who were carefree, undependable, and unambitious in childhood and very unsuccessful in their careers had a whopping increase in their mortality risk."**

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Team Physician
Pro Rodeo Cowboy Association
Professional Bull Riders

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RODEO 101

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3 Things

- Make a difference in the world by creating a lasting legacy
- Educate future generations of orthopaedic surgeons who could make a difference in the low to middle income countries where resources are scarce
- Teach my daughters the importance of generosity and “paying it forward”

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Morgan and Madison McClellan International Research Fellowship

The purpose of the fellowship is to train future leaders in international medicine, foster a culture of collaborative and sustainable partnership, and shape health policy through investigative research.

Fellows spend a year learning to design and conduct on-site research projects that address locally relevant clinical questions. They are embedded in the clinical research program, receiving daily mentorship from experts in the field.

IGOT | INSTITUTE FOR GLOBAL ORTHOPAEDICS & TRAUMATOLOGY

Fellows

- **Sravya Challa** **2017-2018**
  Medical Student, University of California, San Diego

- **Devin Conway** **2016-2017**
  Resident in orthopaedic surgery, Yale University

- **Hao-Hua Wu** **2015-2016**
  Resident in orthopaedic surgery, UCSF

- **Kush Patel** **2013-2014**
  Resident orthopaedic surgery, University of Illinois, Chicago
  Fellow, hand surgery, Mass General Hospital, Boston

- **Iain Elliot** **2012-2013**
  Resident orthopaedic surgery, Uinversity of Utah
  Trauma Fellow, Harborview Medical Center, Seattle

Topics

Anatomy

Biomechanics of Injury

Definition of Injury

Whiplash

Spinal Cord Injury

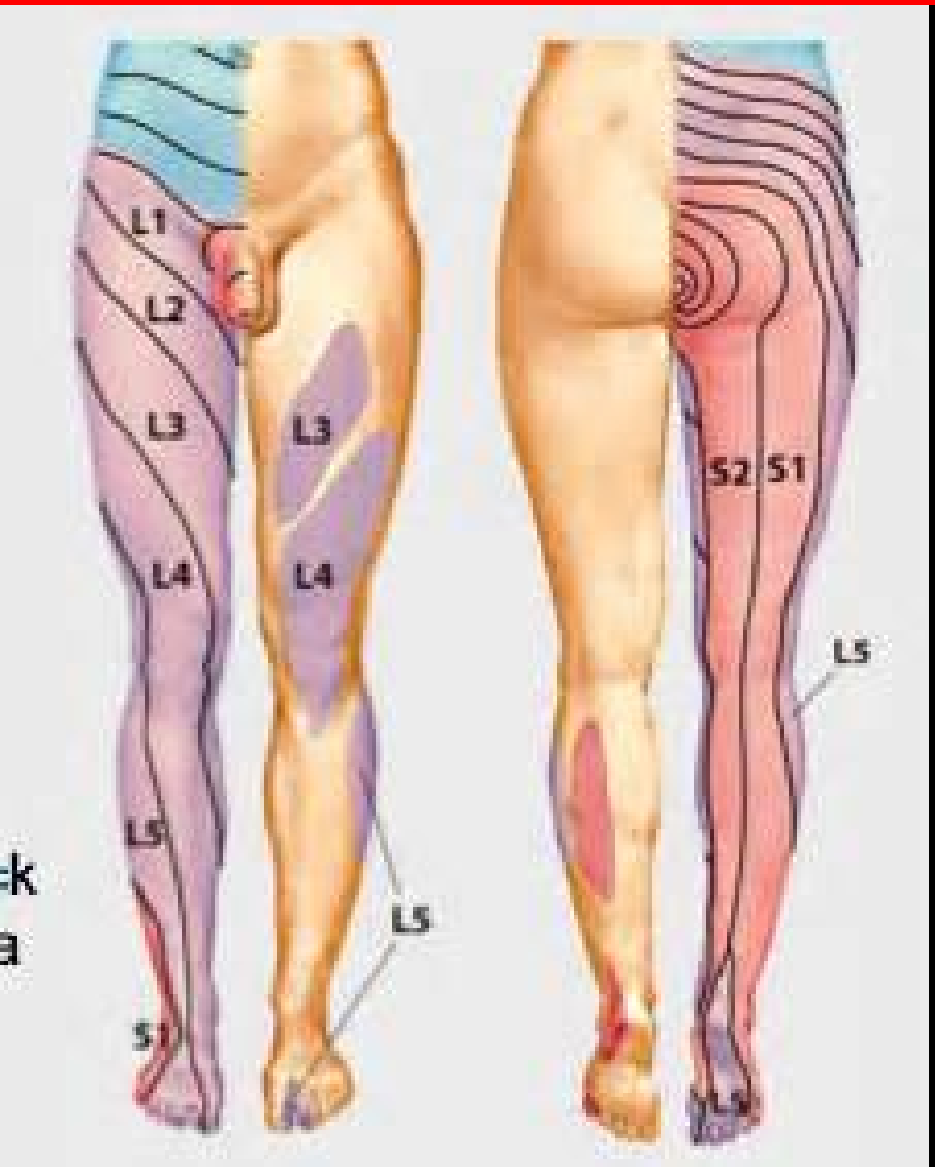
The Herniated Disc

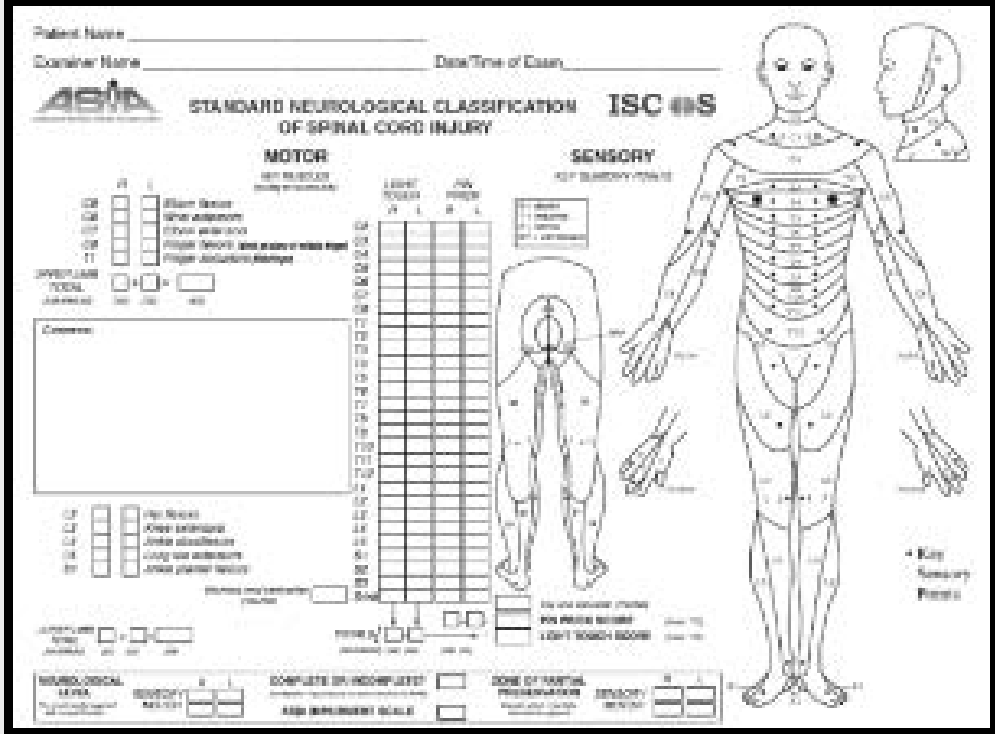
Vertebral Fractures

Diagnosis of Spinal Injury

- History
- Examination
- Imaging Studies
  - X-ray
  - CT scan
  - MRI

Physical Examination





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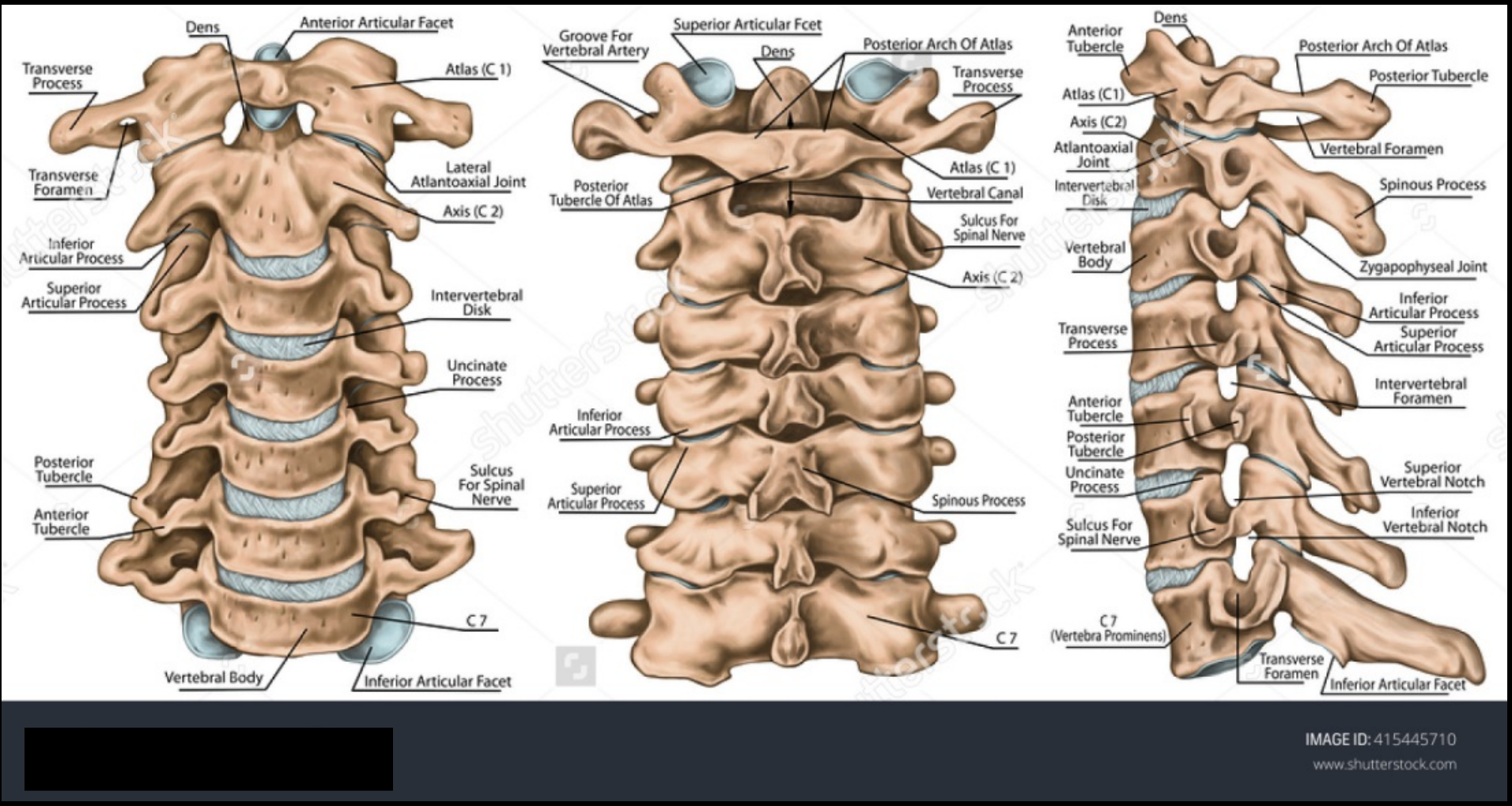
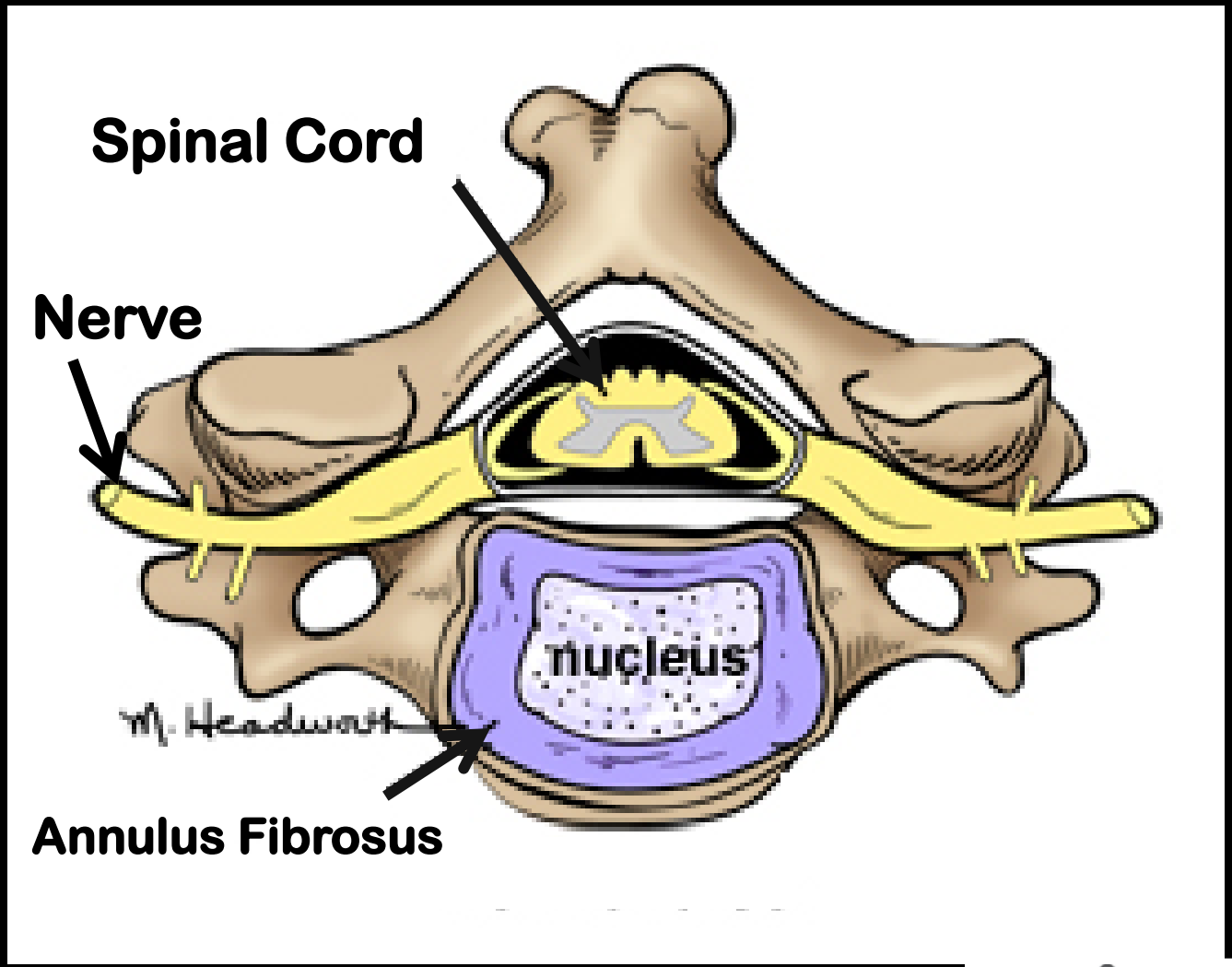
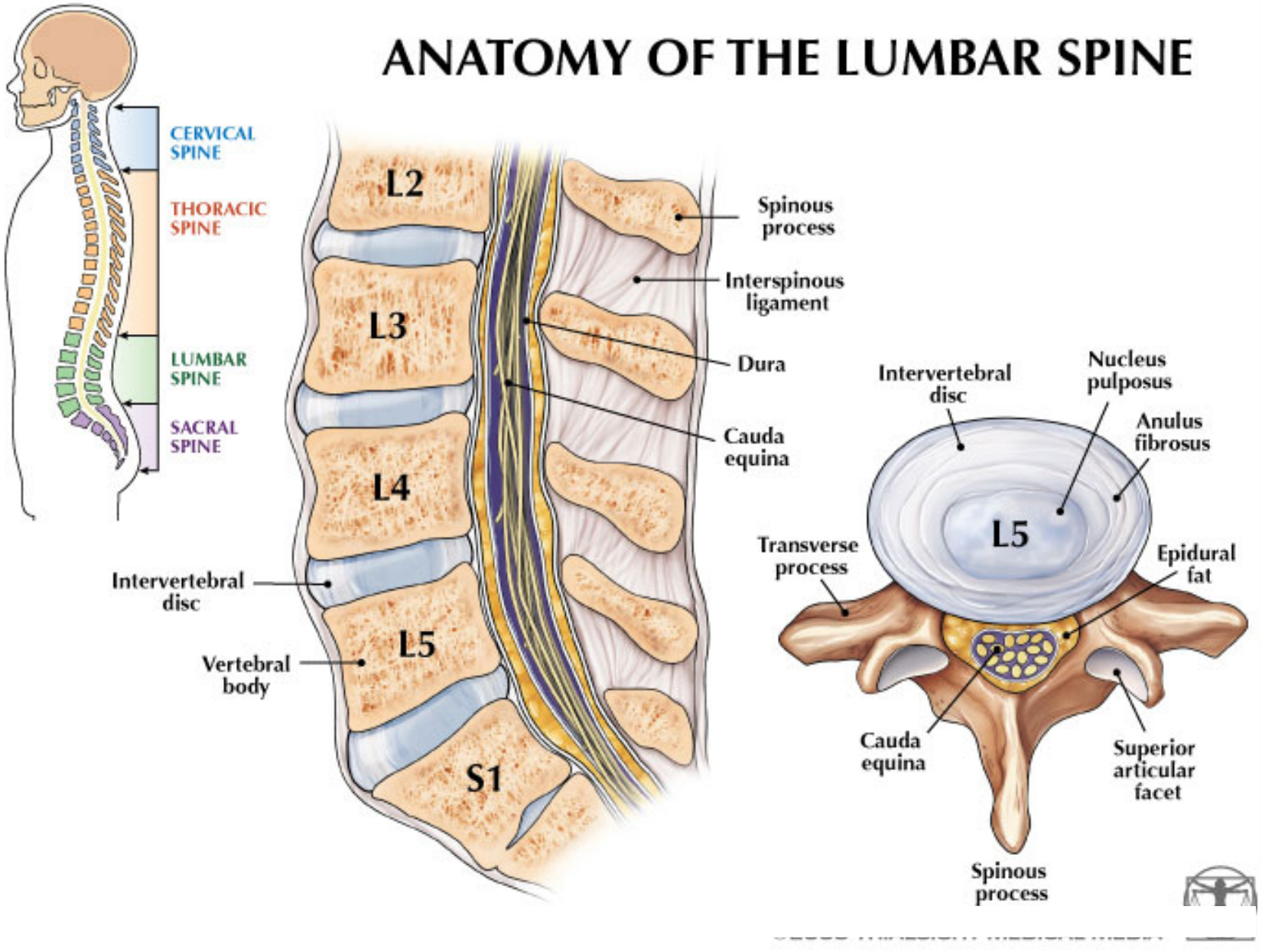
Spinal Anatomy



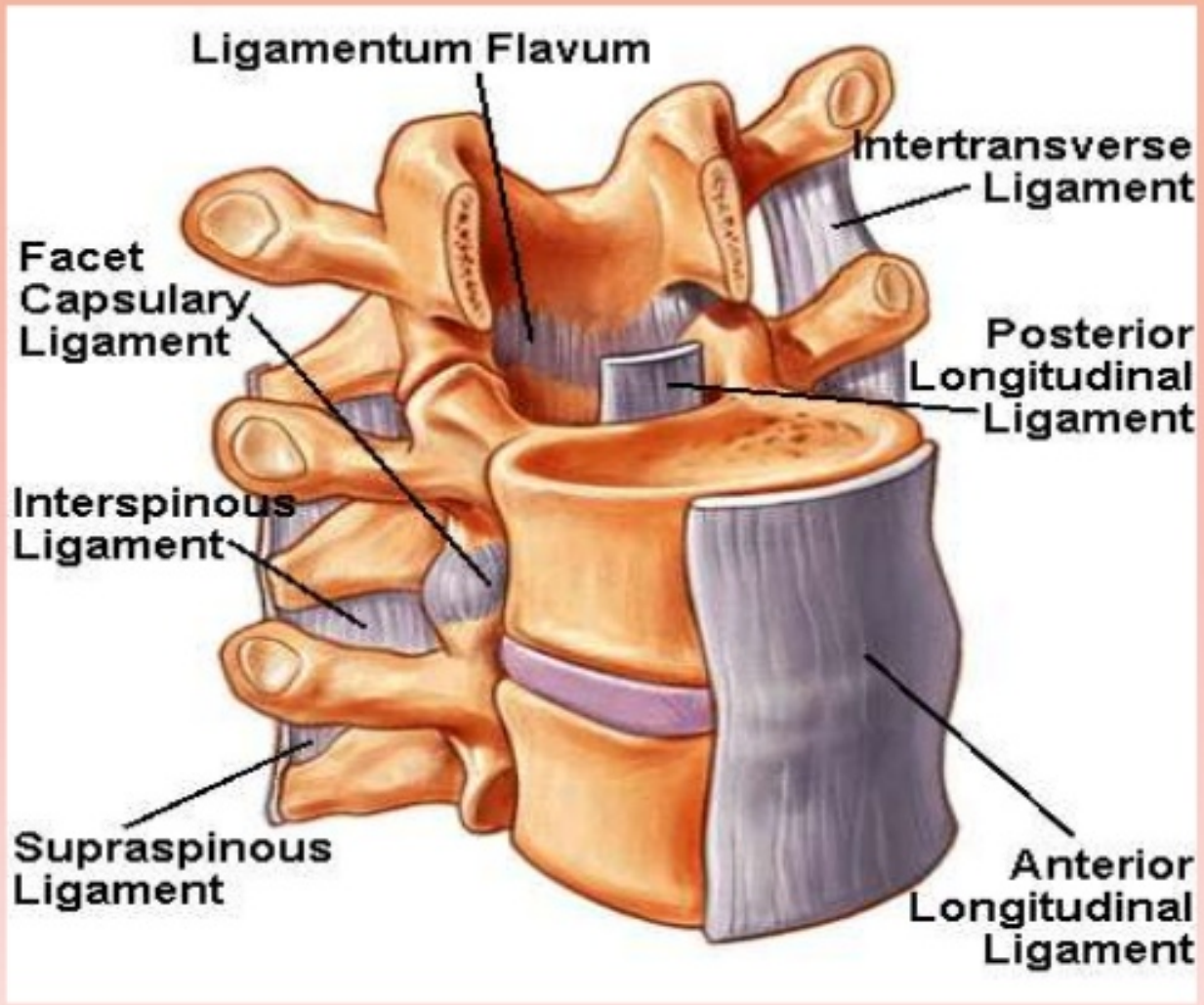
Cross section of Cervical Spine



ANATOMY OF THE LUMBAR SPINE



Spinal Anatomy



What is Injury

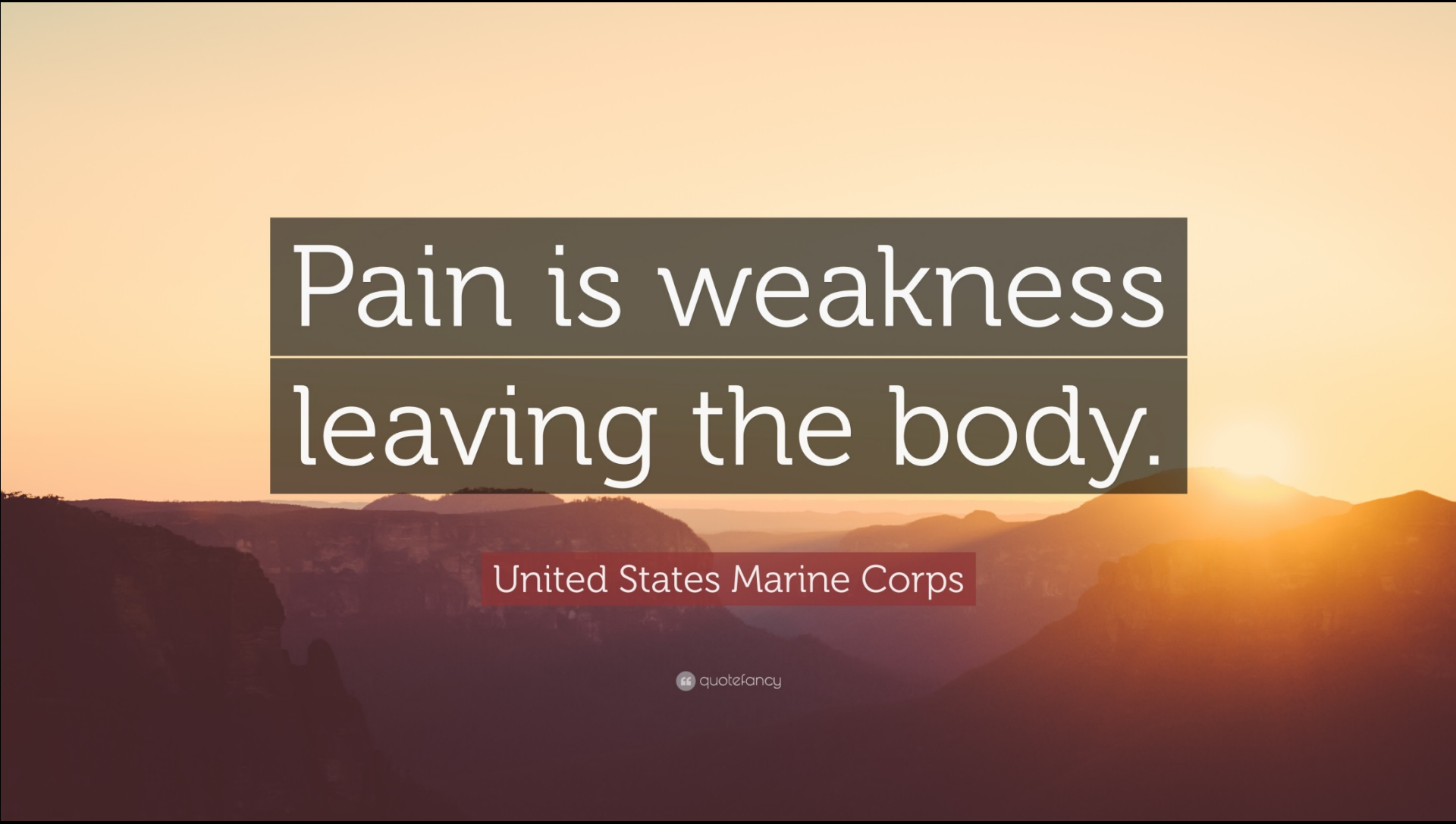
A clear definition is needed

- The definition of injury is fraught with challenges and complexities
- Injuries unlike most diseases must be defined simultaneously by the causative event and by the resulting pathology

Injury

A simple orthopaedic definition

Mechanical disruption of biological tissue resulting in pain



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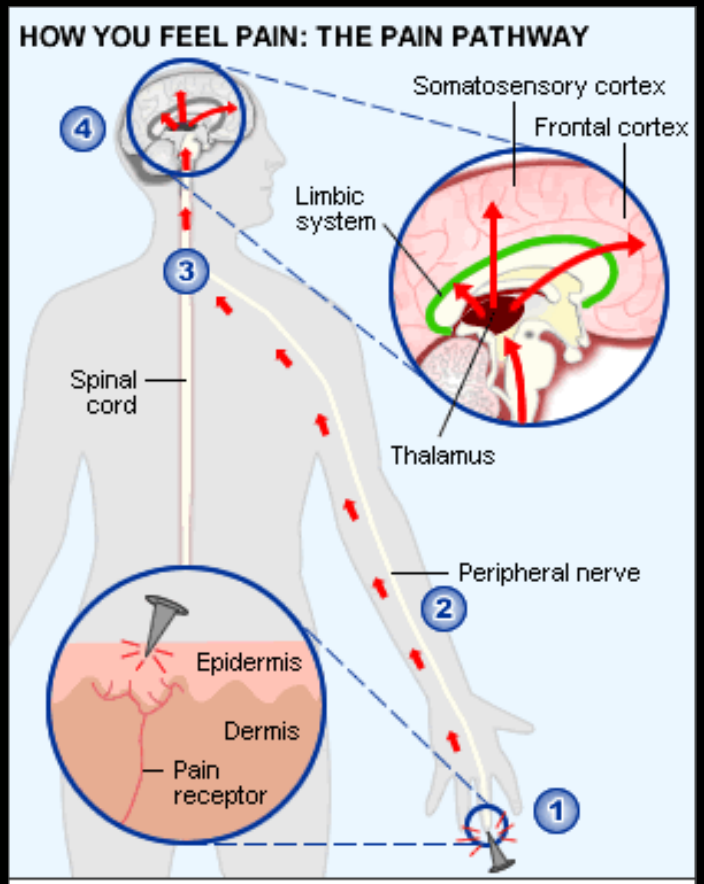
Pain Pathway



1. Pain receptors (nociceptors) in the skin are activated by tissue damage.
2. A signal travels up the peripheral nerve to the spinal cord.
3. Within the spinal cord, chemical messengers (neurotransmitters) are released. These activate other nerves that pass signals to the brain.
4. The thalamus relays the signals on to the somatosensory cortex (sensation), frontal cortex (thinking) and limbic system (emotional response).

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Injury

Theoretical vs. Operational Definition

Notion that an injury must have “sudden discernable effects” leads to the exclusion of tissue damage due to chronic low energy exposures (for example, carpal tunnel syndrome or disc herniation)

Musculoskeletal Injury

There are 4 theories regarding injury causation

Multivariate Interaction Theory

Disruption of mechanical order of a biological system is dependent on the individual components and their mechanical properties. These common denominators will be causally affected by the individual's genetic endowment, morphological characteristics and psychosocial makeup, and by the occupational biomechanical hazards

Differential Fatigue Theory

Unbalanced and asymmetric occupational activities creating differential fatigue and thereby a kinetic and kinematic imbalance resulting in injury precipitation

Cumulative Load Theory

Threshold range of load and repetition product beyond which injury precipitates, as *all material substances have a finite life*

Overexertion Theory

Exertion exceeding the tolerance limit precipitates occupational musculoskeletal injury

Injury is a serious public health issue

Some facts:

- Leading cause of death for people ages 1 to 44 in the US
- 1 person dies from injury every 3 minutes
- More than 2.5 million people are hospitalized with injury each year
- More than 31.6 million people are treated in Emergency Department for injury each year
- More than $465 billion is spent annually in medical costs and lost productivity

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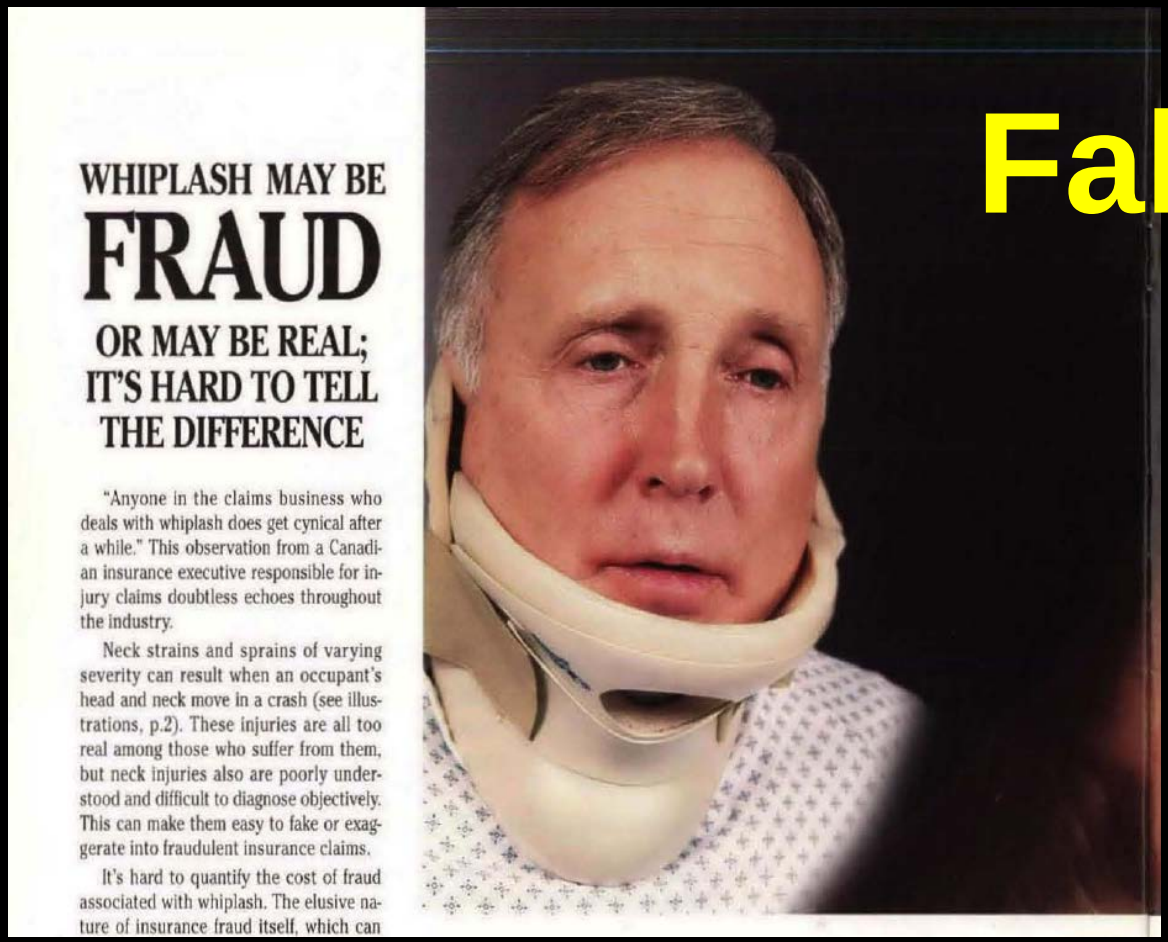
Tweeting:

An MRI obtained following a whiplash injury is necessary to determine the injury ….

FAKE NEWS FOLKS !!!!



WHIPLASH MAY BE

FRAUD

OR MAY BE REAL; IT'S HARD TO TELL THE DIFFERENCE

"Anyone in the claims business who deals with whiplash does get cynical after a while." This observation from a Canadian insurance executive responsible for injury claims doubtless echoes throughout the industry.

Neck strains and sprains of varying severity can result when an occupant's head and neck move in a crash (see illustrations, p.2). These injuries are all too real among those who suffer from them, but neck injuries also are poorly understood and difficult to diagnose objectively. This can make them easy to fake or exaggerate into fraudulent insurance claims.

It's hard to quantify the cost of fraud associated with whiplash. The elusive nature of insurance fraud itself, which can

Fake or Real

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Radiology

Are There Cervical Spine Findings at MR Imaging That Are Specific to Acute Symptomatic Whiplash Injury? A Prospective Controlled Study with Four Experienced Blinded Readers[1]

Purpose: To compare the magnetic resonance (MR) imaging findings in patients with acute whiplash injury with those in matched control subjects.

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Prospective controlled study

100 consecutive patients

MRI within 48 hours after MVA

Compared to 100 age matched controls

4 blinded readers

Conclusion: MR imaging at 1.5 T reveals only limited evidence of specific changes to the cervical spine and the surrounding tissues in patients with acute symptomatic whiplash injury compared with healthy control subjects.

Are early MRI findings correlated with long-lasting symptoms following whiplash injury? A prospective trial with 1-year follow-up

- Trauma-related MRI findings are rare in a whiplash population screened for serious injuries in the emergency unit and not related to a specific symptomatology
- Pre-existing degeneration is not associated with prognosis
- MRI is NOT the answer to a diagnosis in the vast majority of patients developing long-lasting pain after a whiplash injury
- Early MRI scans do not predict prognosis

Alice Kongsted, Joan S. Sorensen, Hans Andersen, Bjarne Keseler, Troels S. Jensen, Tom Bendix

Eur Spine J. 2008 Aug

Eur Spine J (1997) 6:366–375

ORIGINAL ARTICLE

W. H. M. Castro
M. Schilgen
S. Meyer
M. Weber
C. Peuker
K. Wörtler

European Spine Society – The AcroMed Prize for Spinal Research 1997

Do "whiplash injuries" occur in low-speed rear impacts?

Volunteers

14 M + 5 F

Delta V of up to 14.2 km/h and mean acceleration up to 3.6 g
Clinical and MRI examination before and after the rear-end collisions

No persistent symptoms or changes on MRI

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Biomechanical “limit of harmlessness”

Delta V **< 10 mph**

Eur Spine J (1997) 6:366–375

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Do “whiplash injuries” occur in low-speed rear impacts?

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What would the findings be if we could expose a human subject to 10X the G force in the 1997 Castro paper….

Delta V of up to 14.2 km/h and mean acceleration up to 3.6 g
No clinical or MRI findings

Eur Spine J (1997) 6:366–375

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Do "whiplash injuries" occur in low-speed rear impacts?

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Prospective Clinical Assessment of the Cervical Spine in Professional Rodeo Riders After Exposure to Greater than 10g Linear Acceleration

nstitute
HOSPITAL

Co-authors

Jeremie Larouche, M.D
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Safa Herfat, PhD
Christopher Hess, M.D., PhD
Jared Narvid, M.D.
Alisa Gean, M.D.

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Pilot Study

- UCSF IRB approval
- Volunteers ? (American Cowboys)
- Concussion / TBI
- Whiplash / cervical injury

Volunteers….

The Most Dangerous 8 Seconds in Sport

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Study

- Complete pre and post ride survey
- Medical history and exam
- SF 36, VAS, NDI, Scat 3
- Brain and Cervical MRI
- Oculomotor testing
- G force calculations

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MRI pre and post ride in 6 riders within 24 hours

Neuro Kinetics

The I-Portal® neuro-otologic / neuro-physiologic test platform
Using oculomotor, optokinetic and vestibular tests

Vector Mouthguard

i1 Biometrics

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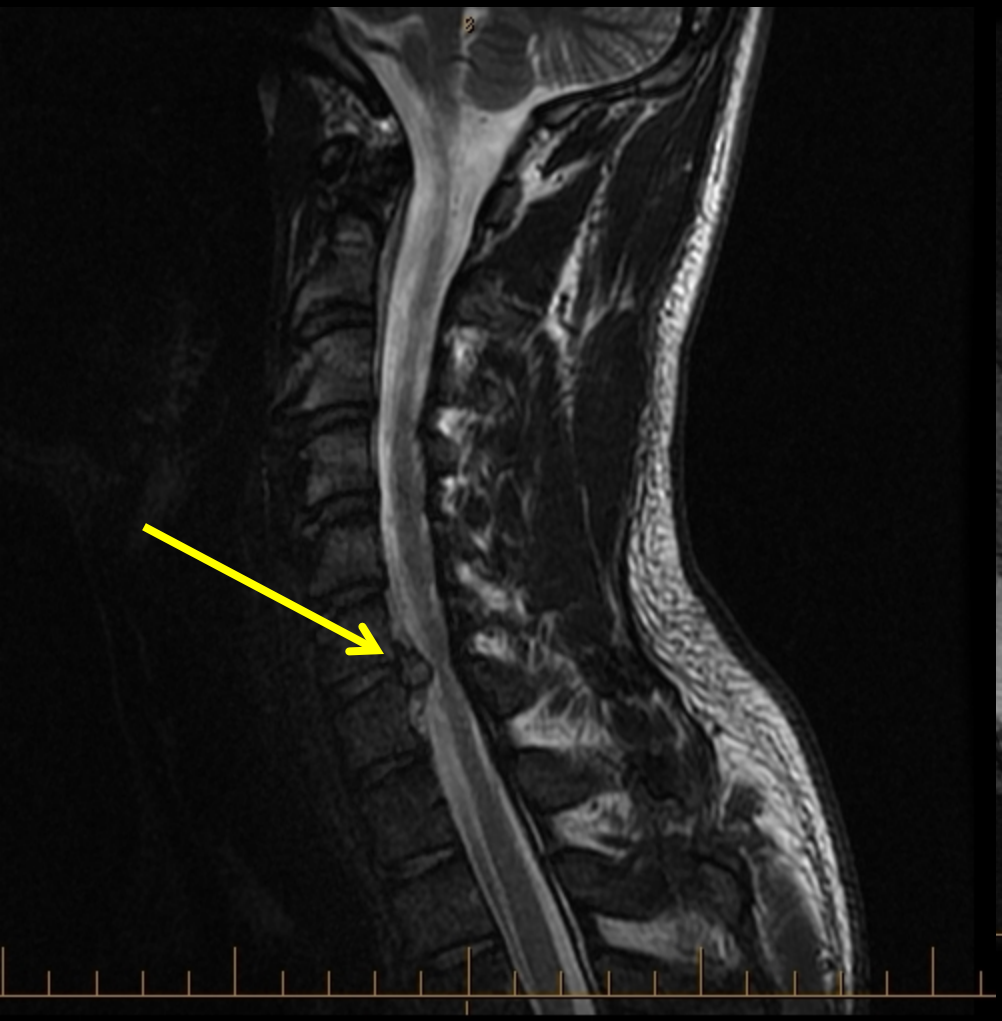
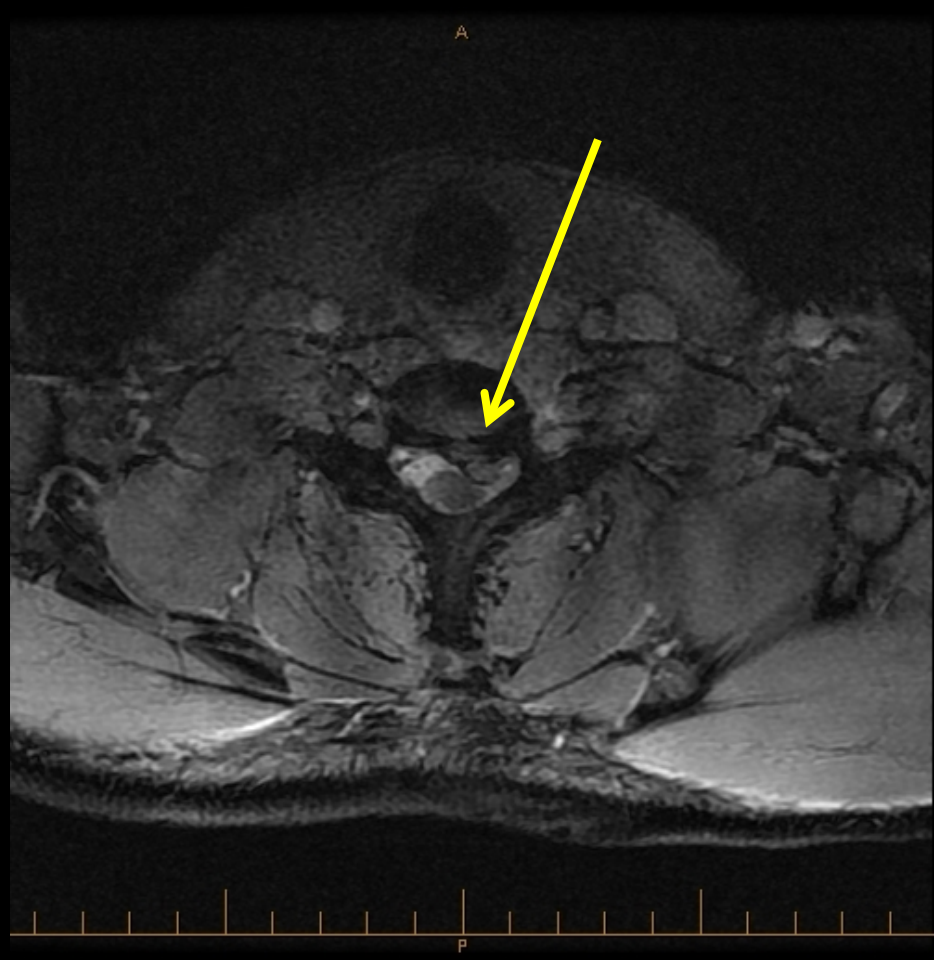
BBR 6 Pre Ride MRI

C6-C7 paracentral herniation





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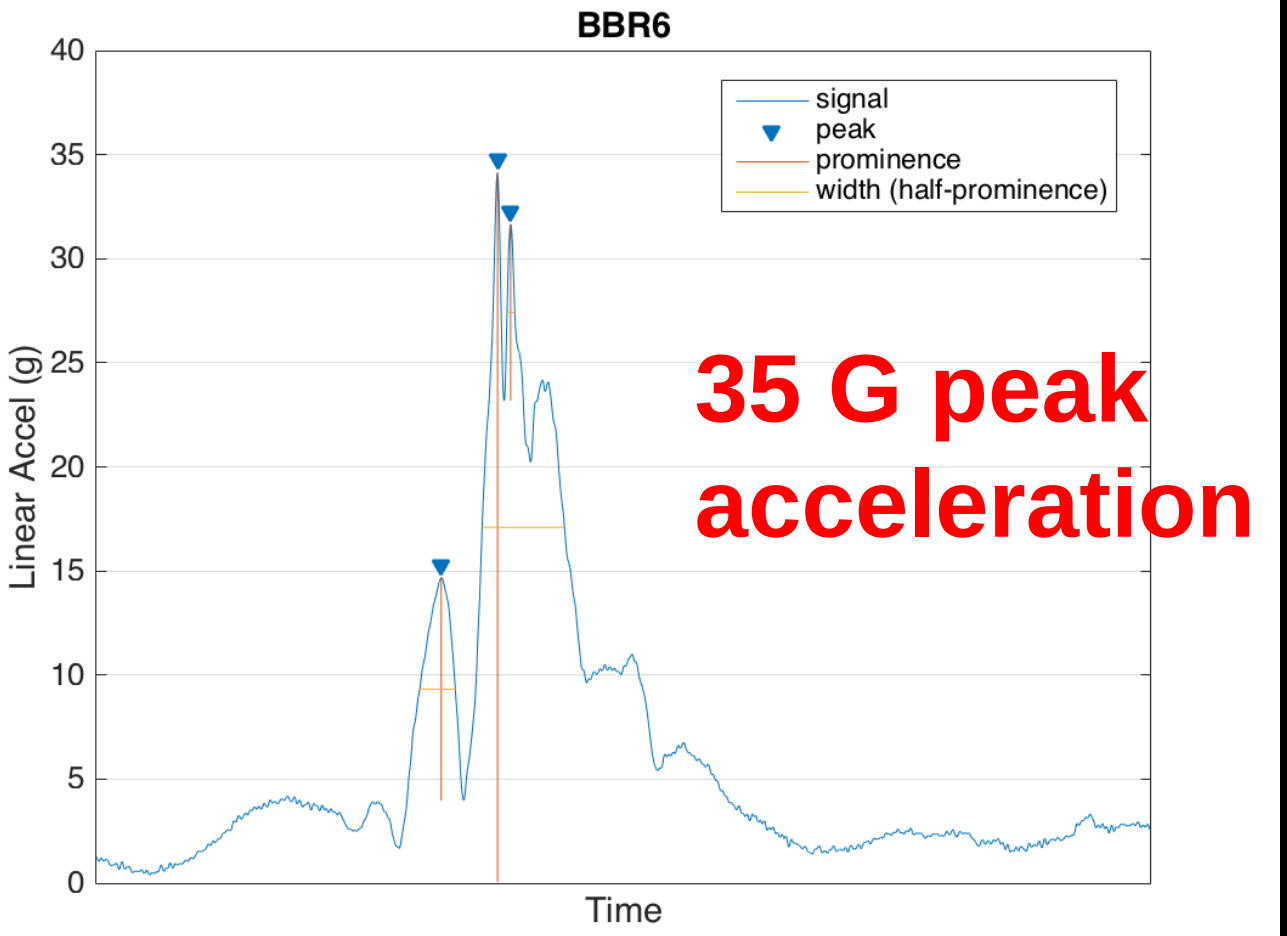
Vector Mouthguard Data



35 G peak acceleration

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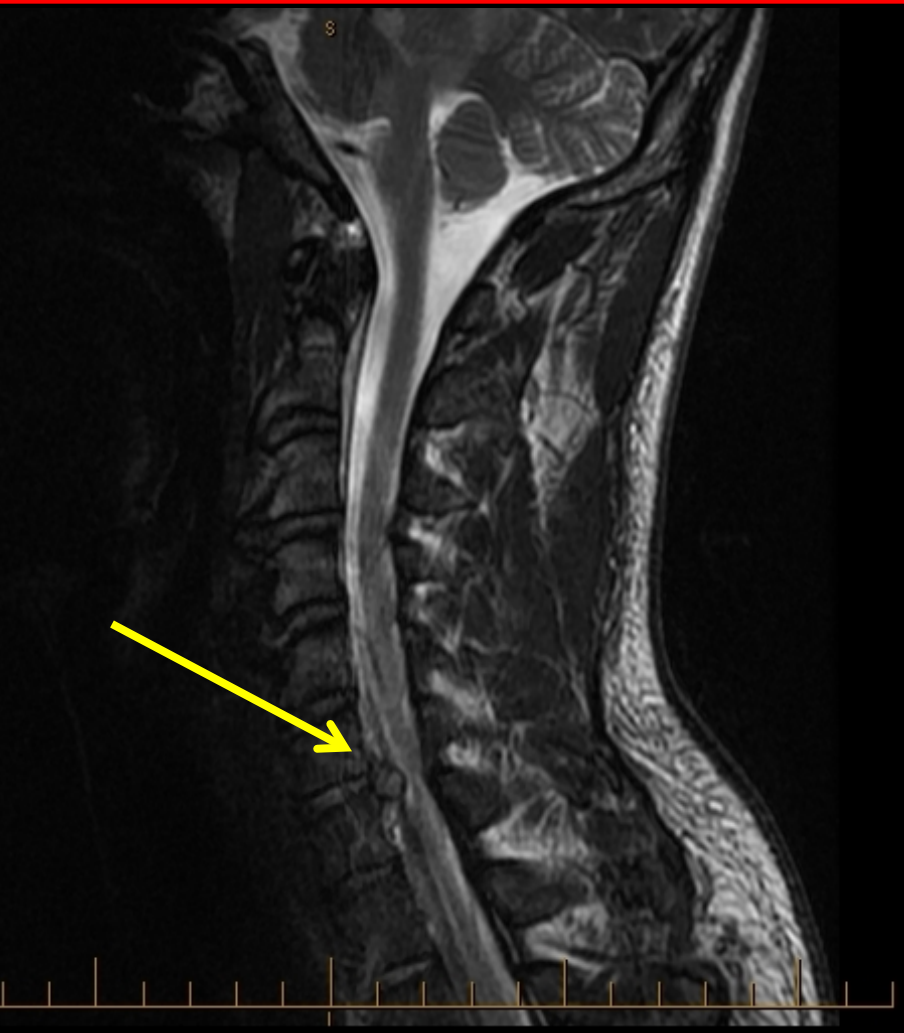
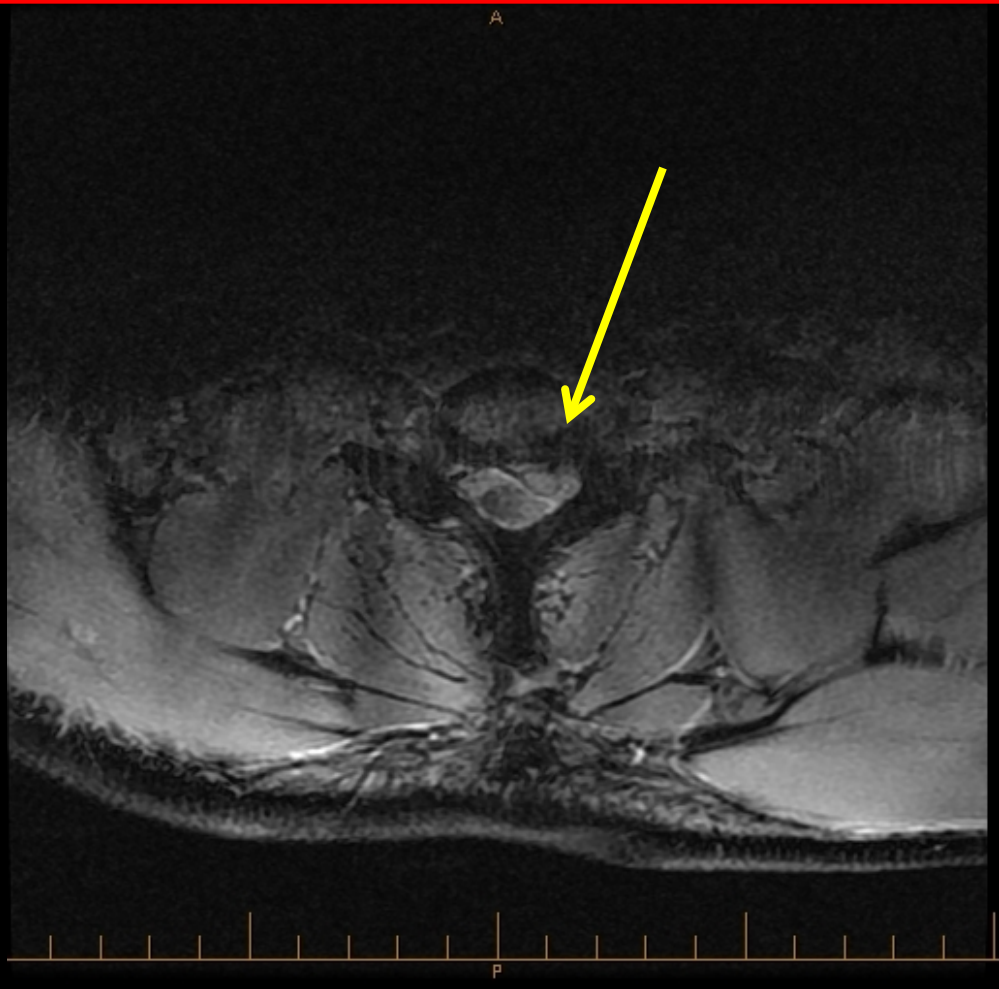
BBR 6 Post Ride

C6-C7 paracentral herniation





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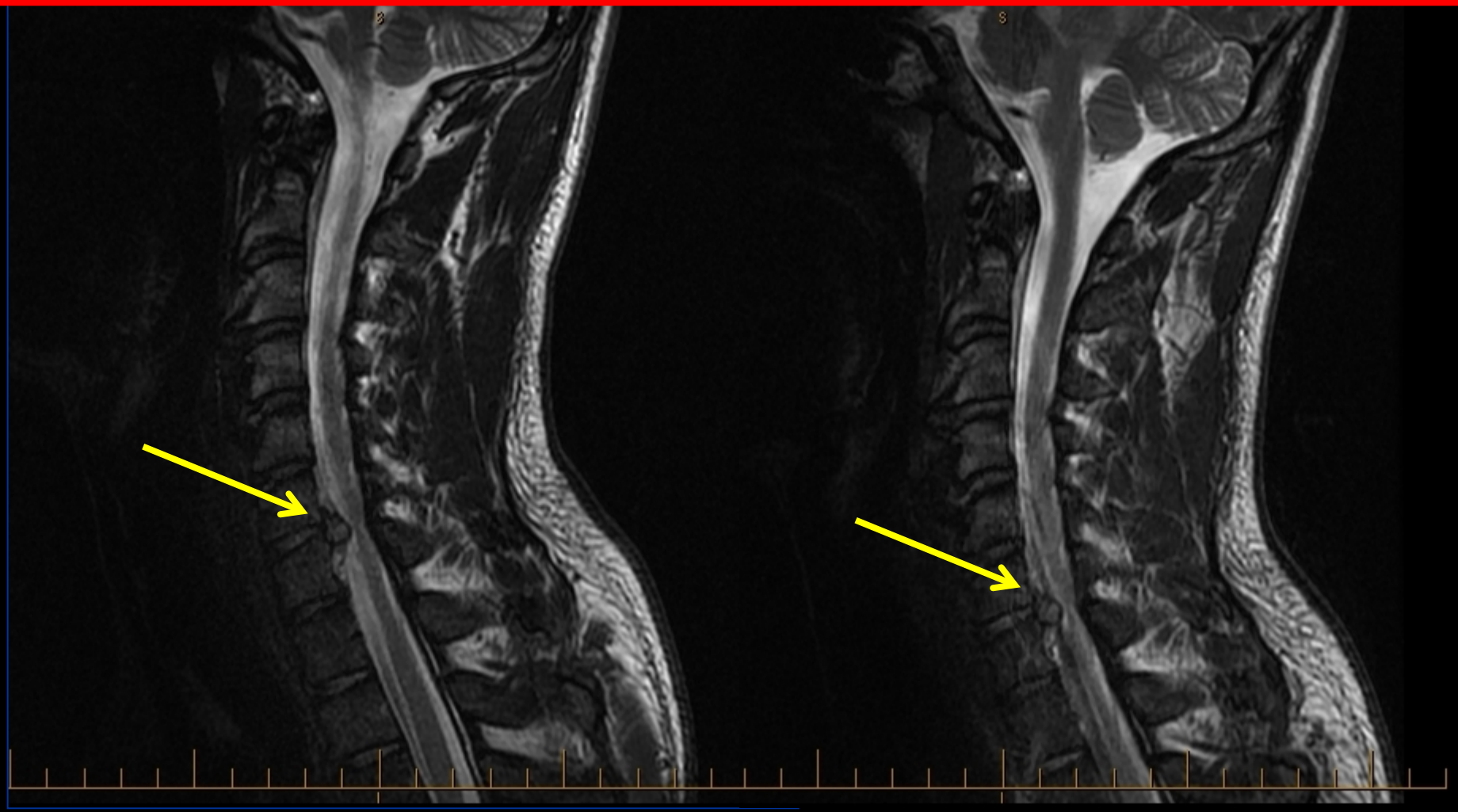
Before and After Ride



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Results

- Twenty-one male professional roughstock riders (bareback-8, saddle bronc-7, bull-6; average age 24.3±5.6 years) were enrolled.

- 17 riders' mouth-guards recorded events >10g.
- Mean linear acceleration **23.8 ± 13.9g.**
- Peak linear acceleration **62.8g.**

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Results

- Post-ride VAS for neck pain trended towards higher scores although the difference was not significant (pre: 0.48 *v.* post: 1.0; p=0.10).
- Post-ride VAS scores for arm pain were not significantly different from pre-ride scores (p>0.25).
- Mild disk bulging adjacent to pre-existing disease was noted in 2/6 post-ride MRI scans but no clinically significant changes were identified.

Treatment

In 1995, on the basis of a systematic review of the literature on whiplash injury

Spitzer et al. recommended

minimal intervention

reassurance and encouragement to resume normal activity

simple exercises to be performed at home for acute injury

They found little support for other treatment approaches

No Pain No Gain

At 1-year follow-up
73 participants had returned to work
37 remained work-disabled
Participants who returned to work were more likely to maintain treatment gains (77.5%) than participants who remained work-disabled (48%), $\chi^2 = 6.3$, $P < 0.01$.

Sullivan, Michael; Adams, Heather; Thibault, Pascal; Moore, Emily; Carriere, Junie S; Larivière, Christian

PAIN: May 2017

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Doctor

Impairment vs Disability

Impairments: Loss of physiological or psychological function due to an injury, illness, or congenital (inborn) condition.

Disability: Loss or limitation of opportunities to take part in society on an equal level due to social and environmental barriers.

Judge

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Disability

Lower back pain is the top cause for years lost due to disability

Data from 117 studies from 47 different countries

Annals of Rheumatic Diseases

The global burden of occupationally related low back pain: estimates from the Global Burden of Disease 2010 study
T Driscoll, G Jacklyn, J Orchard, E Passmore, T Vos, G Freedman, S Lim, L Punnett

Disability

Social Security receives more disability applications for back problems than for any other physical illness or injury

To get disability benefits, you must have a "medically determinable" back impairment such as spinal stenosis, nerve root compression, herniated disc (if it's chronic and not treatable), or fracture

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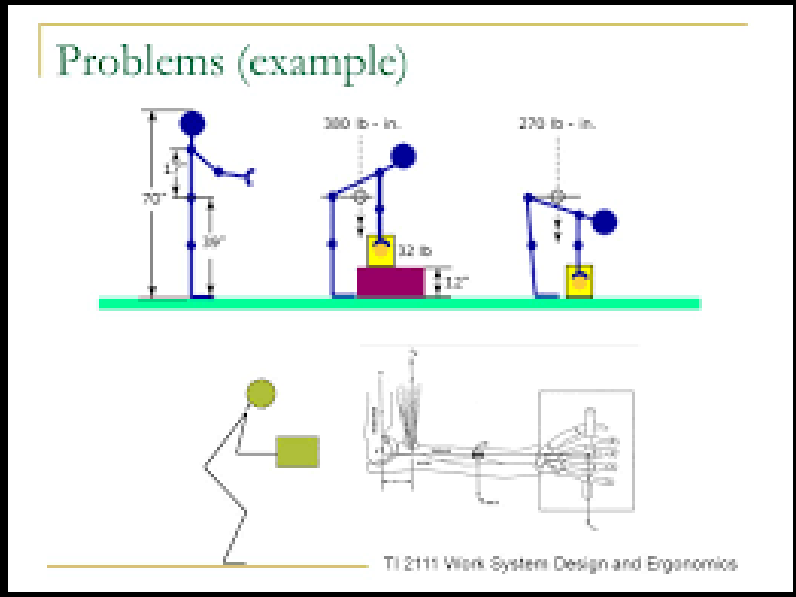
What is Biomechanics ?

study of the mechanical laws relating to the movement or structure of living organisms

Evaluating the injury mechanism

- mathematical modelling
- cadaver studies
- human volunteers
- dummys



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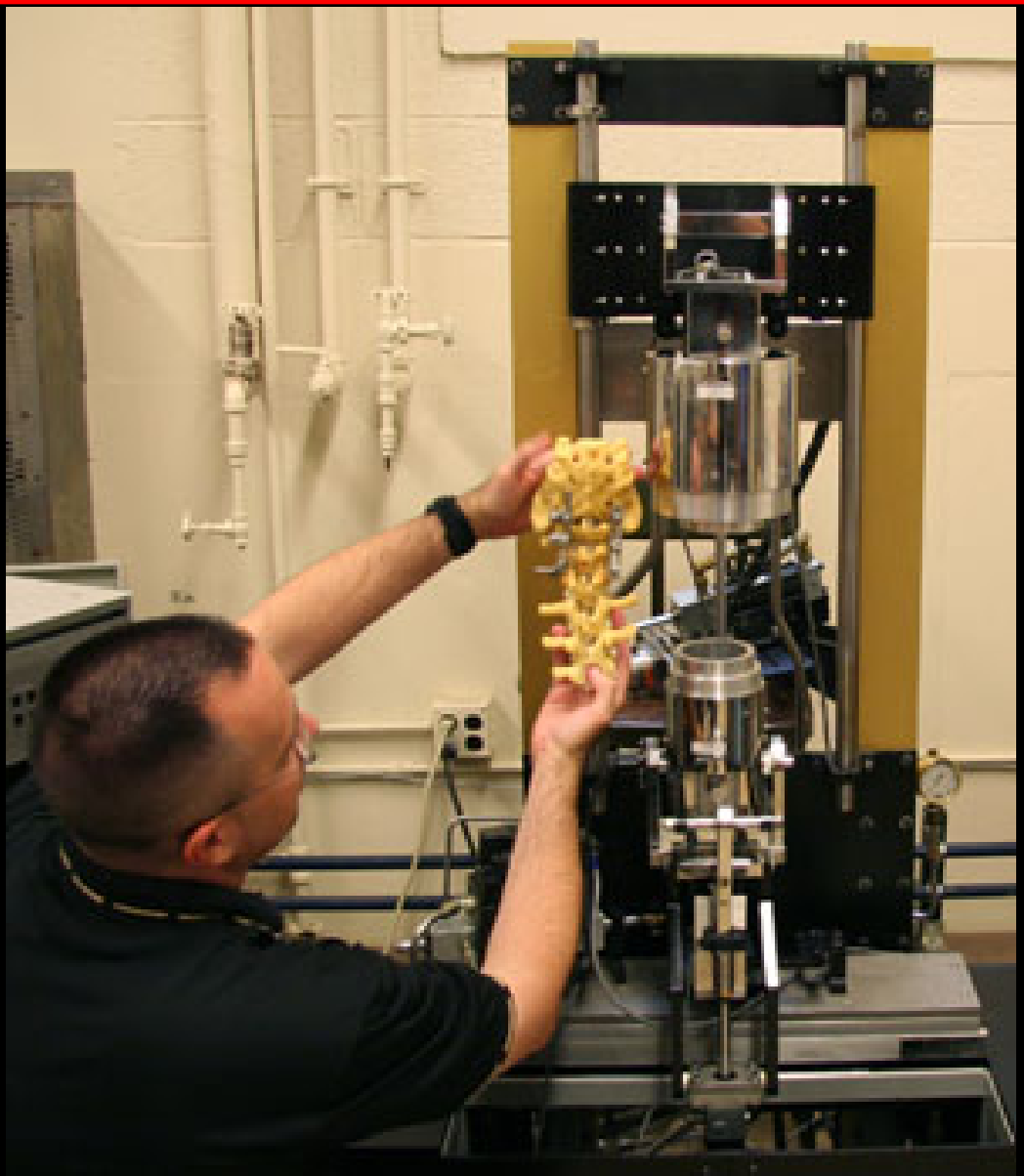
Three biomechanical regions

T1-T8:
relatively rigid (ribcage),
kyphosis.
flexion injury pattern predominates

T9-L2:
transition: immobile - mobile,
transition: kyphosis - lordosis
most injuries occur here

L3-sacrum:
mobile, lordosis
axial load injuries predominate

Biomechanics



In vitro biomechanical testing of the spine requires highly specialized testing machines and devices for measuring loads and displacements

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Disc Pressure in Human Volunteer

For lifting a load of 20 kg with bent posture and straight legs, study found a 4.5 fold increase

SPINE Volume 24, Number 8, pp 755–762

New *In Vivo* Measurements of Pressures in the Intervertebral Disc in Daily Life

Hans–Joachim Wilke, PhD,* Peter Neef, MD,† Marco Caimi, MD,‡ Thomas Hoogland, MD,§ and Lutz E. Claes, PhD*

Disc Pressure in Human Volunteer

Pressure increased after 7 hours in the lying position to 240% of its pressure at the time of going to bed

? presumably because of rehydration of the disc

SPINE Volume 24, Number 8, pp 755–762

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Biomechanics

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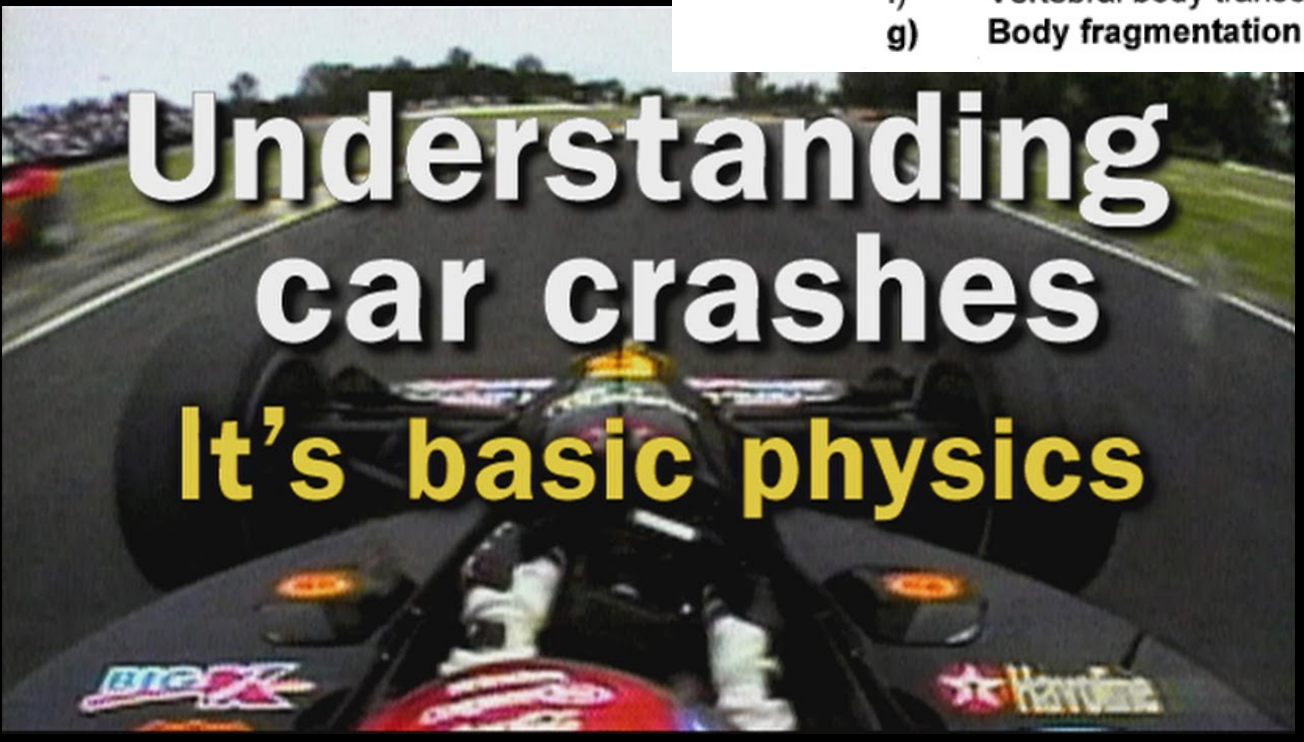
Biomechanics

B. Decelerative Injuries

1. Note that human bodies are more resistant to disruption than aircraft. Thus the accident victims may be the best source for evidence with which to reconstruct the mishap sequence.
2. Pure decelerative injuries provide a medical scale for estimation of crash forces. The most reliable points on this rough scale are highlighted in the list below.
   - **a) Vertebral body compression -- 20 - 30 Gz**
   - b) Fracture dislocation C1-C2 -- 20 - 40 G
   - **c) Aorta intimal tear -- 50 G**
   - **d) Aorta transection -- 80 - 100 G**
   - e) Pelvic fractures -- 100 - 200 G
   - f) Vertebral body transection -- 200 - 300 G
   - **g) Body fragmentation -- > 350G**



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CURRENT CONCEPTS REVIEW

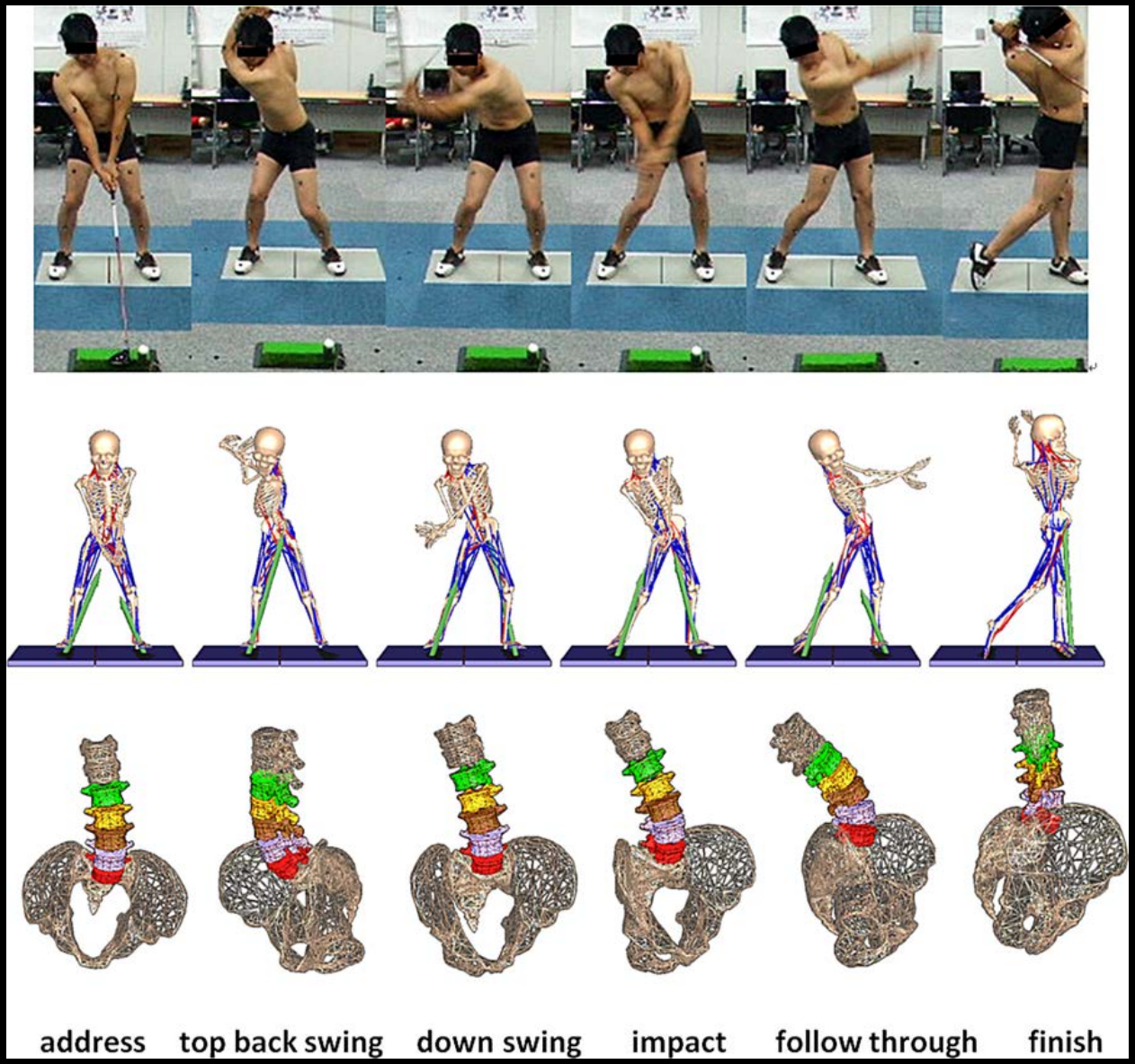
LOW-BACK PAIN IN ATHLETES

BY CHRISTOPHER M. BONO, MD

Investigation performed at the Department of Orthopaedic Surgery, Boston University Medical Center, Boston, Massachusetts

Back pain is a common reason for lost playing time by competitive athletes. McCarroll et al.[1] reported that low-back pain accounted for loss of playing time by 30% (forty-four) of 145 college football players. Hainline[2] found that 38% of professional tennis players reported low-back pain as the reason for missing at least one tournament. Ninety percent of all tour injuries in professional golfers involve the neck or back[3].

Biomechanics



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Biomechanics

Hosea and colleagues (32) were some of the first researchers to investigate forces on the lower back during a full golf swing. They calculated the compressive, shear, lateral-bending and rotational loads on the L3-4 segment of the lumbar spine during golf swings using a five iron. Kinetic, kinematic and surface EMG data were collected from four professional (mean age-37 years) and four amateur (mean age-34 years) golfers. The amateur golfers recorded higher average peak shear loads (596 N compared with 329 N for the professionals), while compressive load was considerably higher amongst the professionals (7584 N versus 6100 N). These average compressive loads represent forces equivalent to about 8 times body weight.

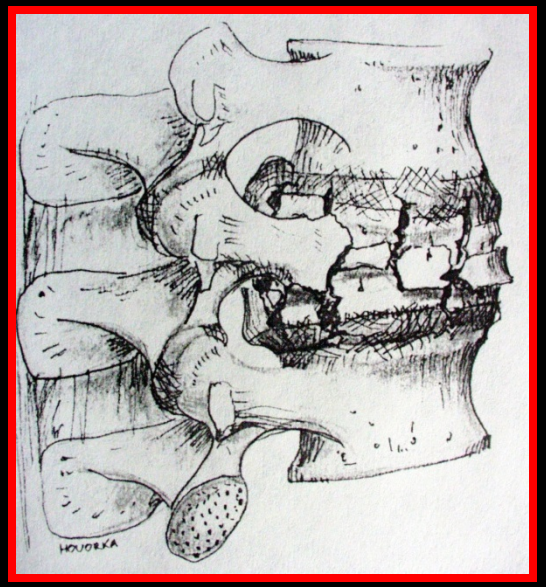
Biomechanics

The results from Hosea et al. (32) experiment would appear to show that the golf swing produces sufficient force to potentially injure the lumbar spine. In some cases the injury may occur as a traumatic event while in other cases the mechanism may have a more insidious onset. Insidious LBP is thought to be associated with a process known as the cumulative load theory (35). This theory takes into

Examples of Spinal Injury

Fracture or “Broken Back”

Fall from height
Burst Fracture



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Spinal Cord Injuries

- Spinal Cord Injuries 2010 -2015
- Causes of SCI have changed drastically since 2010
- Vehicular 38%
- Falls 30%
- Violence (primarily gunshot wounds) 14%
- Sports/Recreation Activities 9%
- Medical/Surgical 5%
- Other 4%
- As of 2015, 12,500 new SCI occur each year and between 240,000 and 337,000 people are currently living with SCI in the United States

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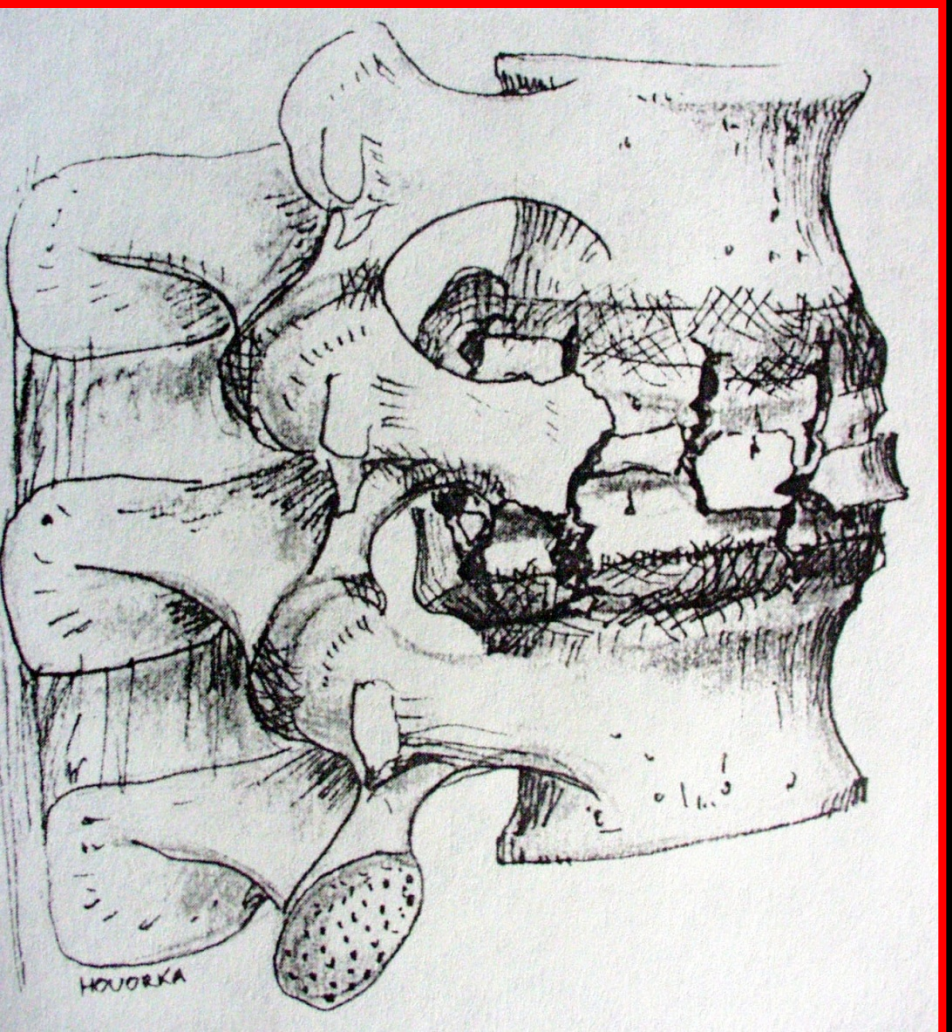
Burst Fracture



Burst fracture: 2

posterior ligaments intact: 0

neurologic intact: 0

TLICS : 2

TLSO 3 - 4 months

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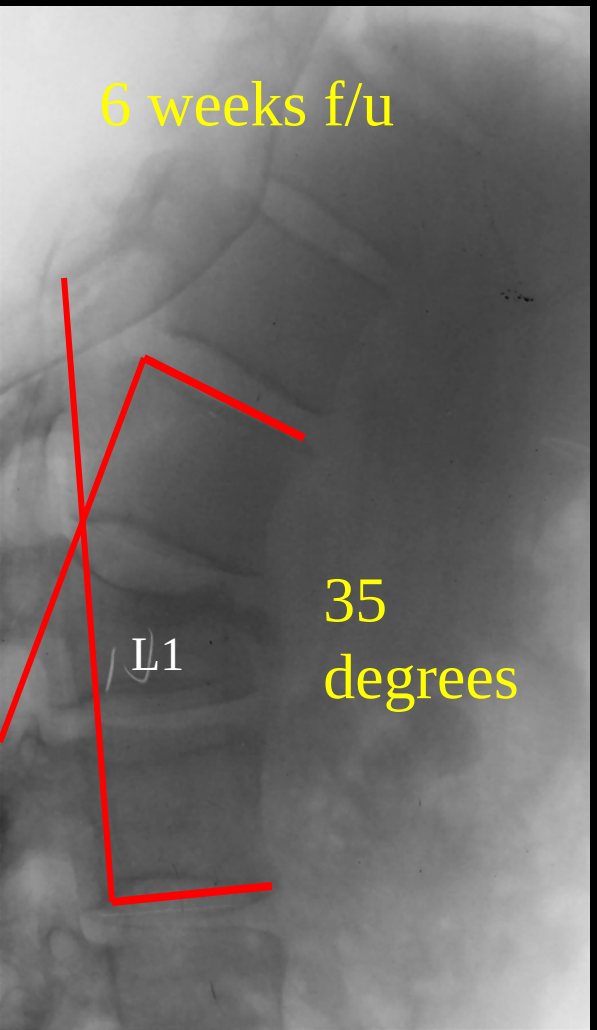
L1 Burst Fracture

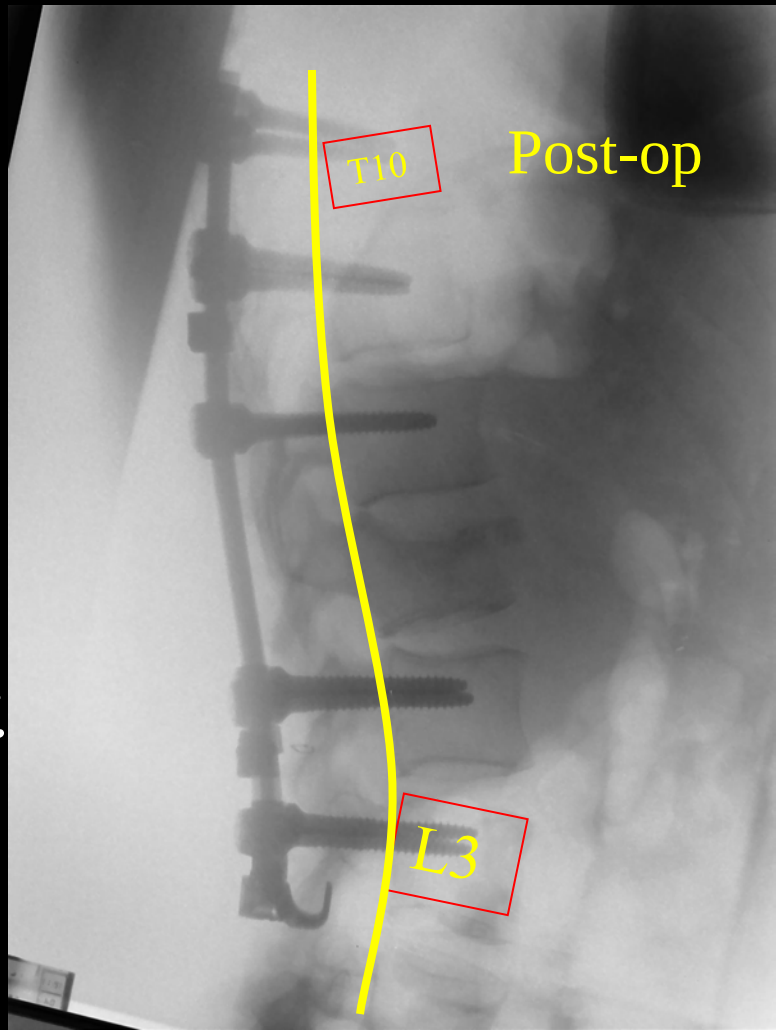
Neuro intact intially treated in TLSO

L1 Burst Fracture



Loss of posterior ligamentous stability

PLC incompetent

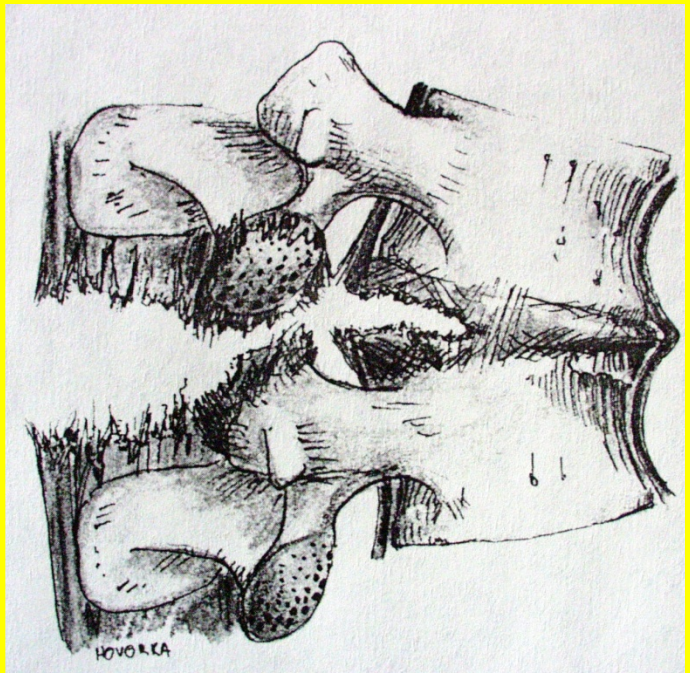


Flexion - Distraction Injury

Various combination of injuries :
Treatment dependent on bony vs. ligamentous injury

1 level bone

1 level discoligamentous

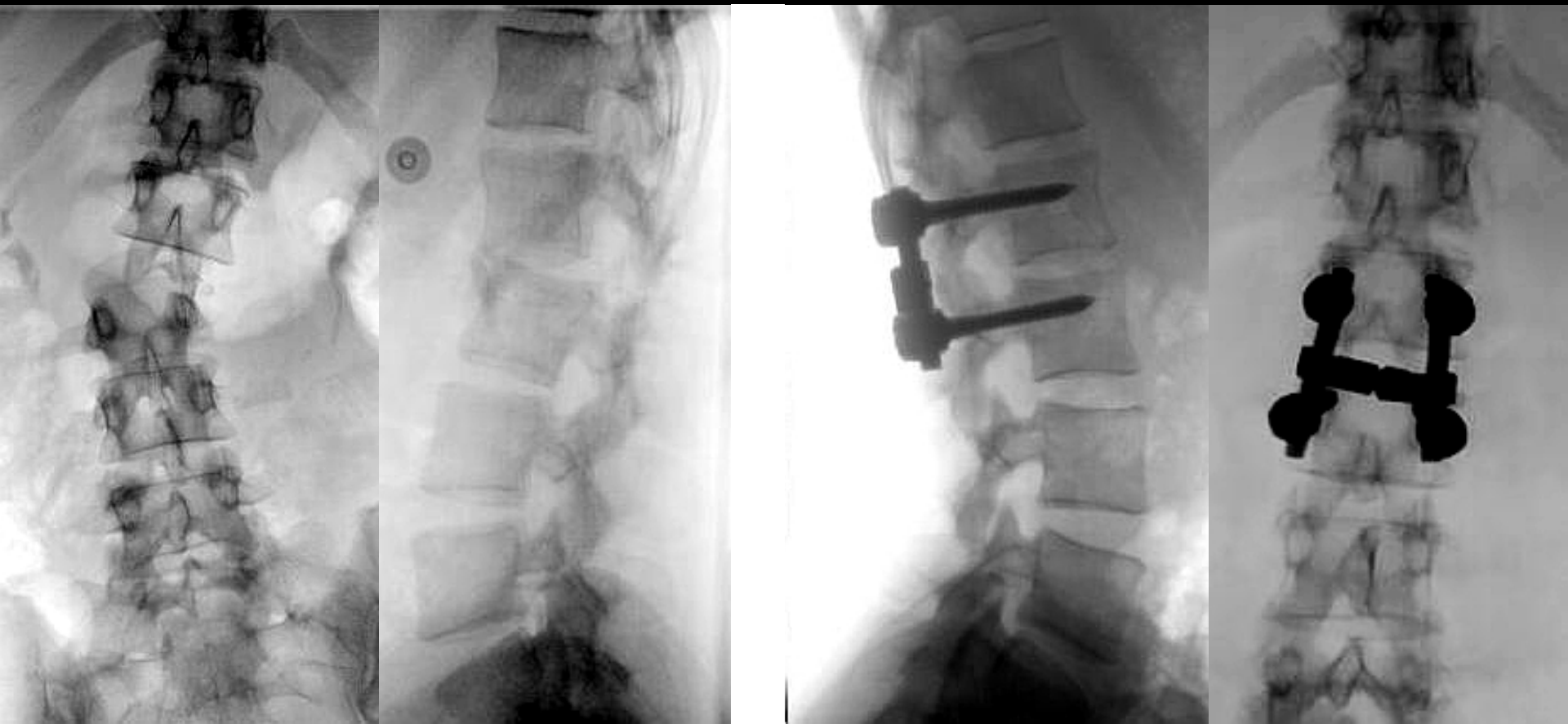


2 level ligamentous

Flexion - Distraction Injury

TLICS : morphology 4, PLC 3, neuro 0

TLICS = 7 = SURGERY



L3 Flexion – Distraction Injury

TLICS : morphology 4, PLC 3, neuro 3 (CE)

TLICS = 10

Complete SCI

Posterior fixation with compression construct

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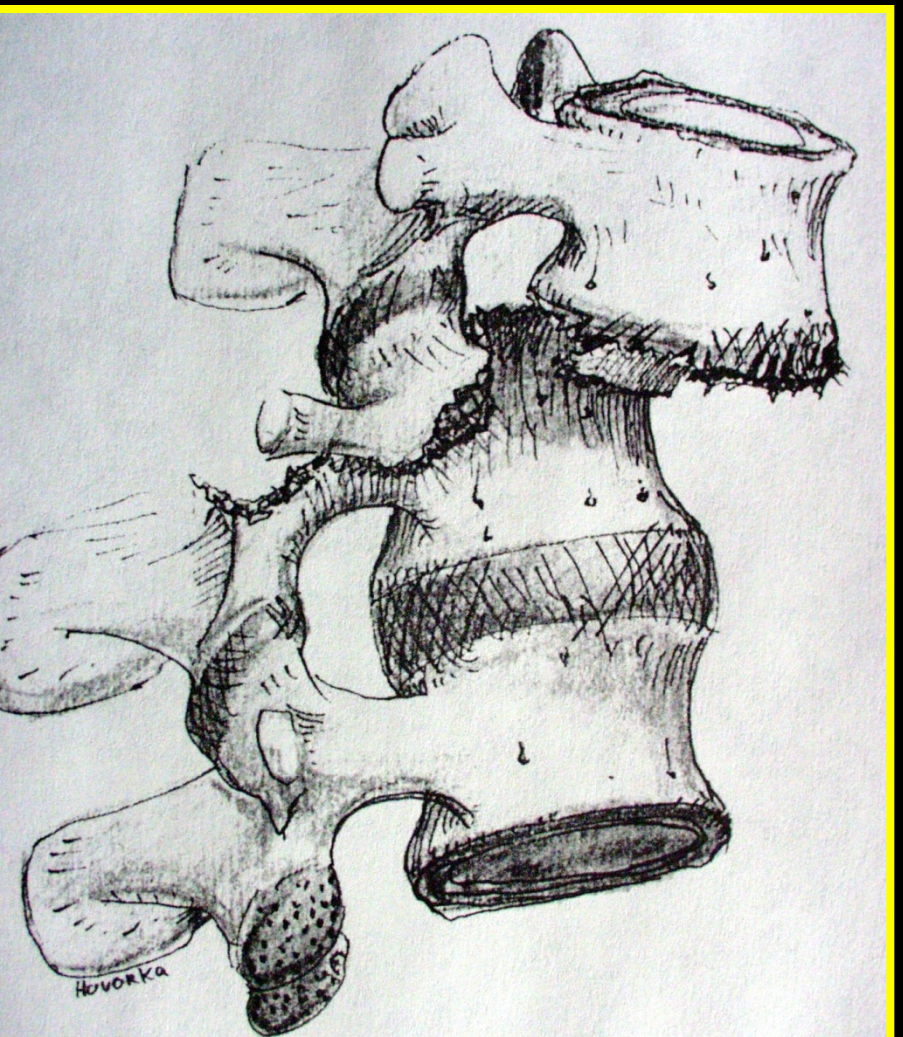
Fracture - Dislocations



Flexion - Rotation Fracture
Shear Fracture
3 column injuries

High incidence of neurologic deficits

Highly unstable

Majority require surgery

Long posterior neutralization construct with segmental fixation

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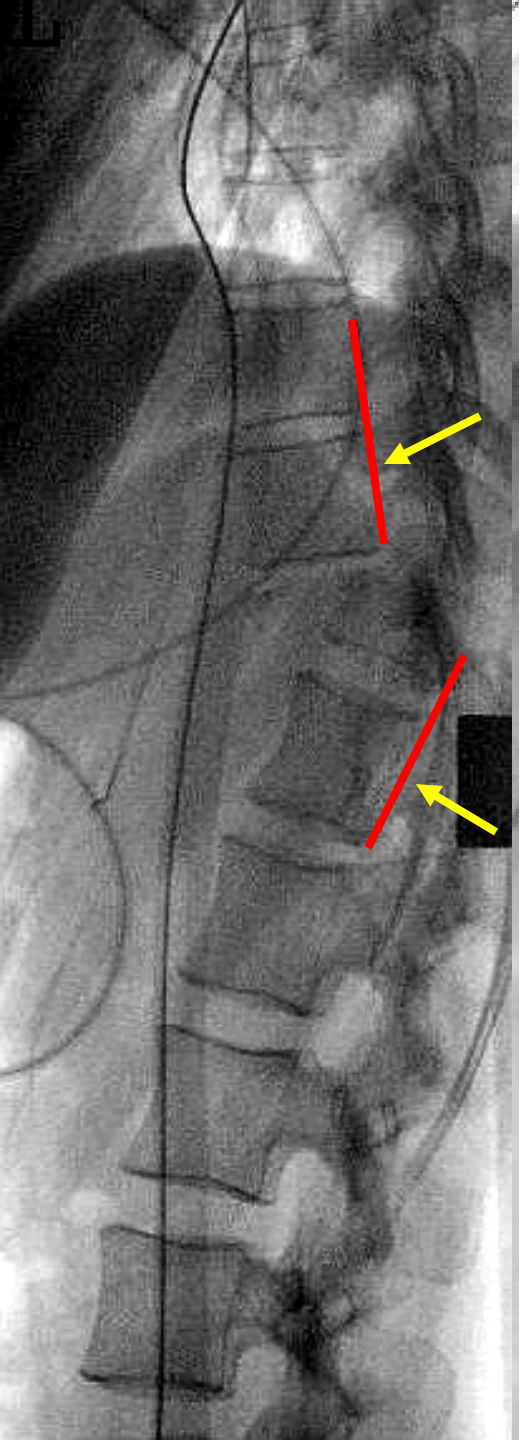

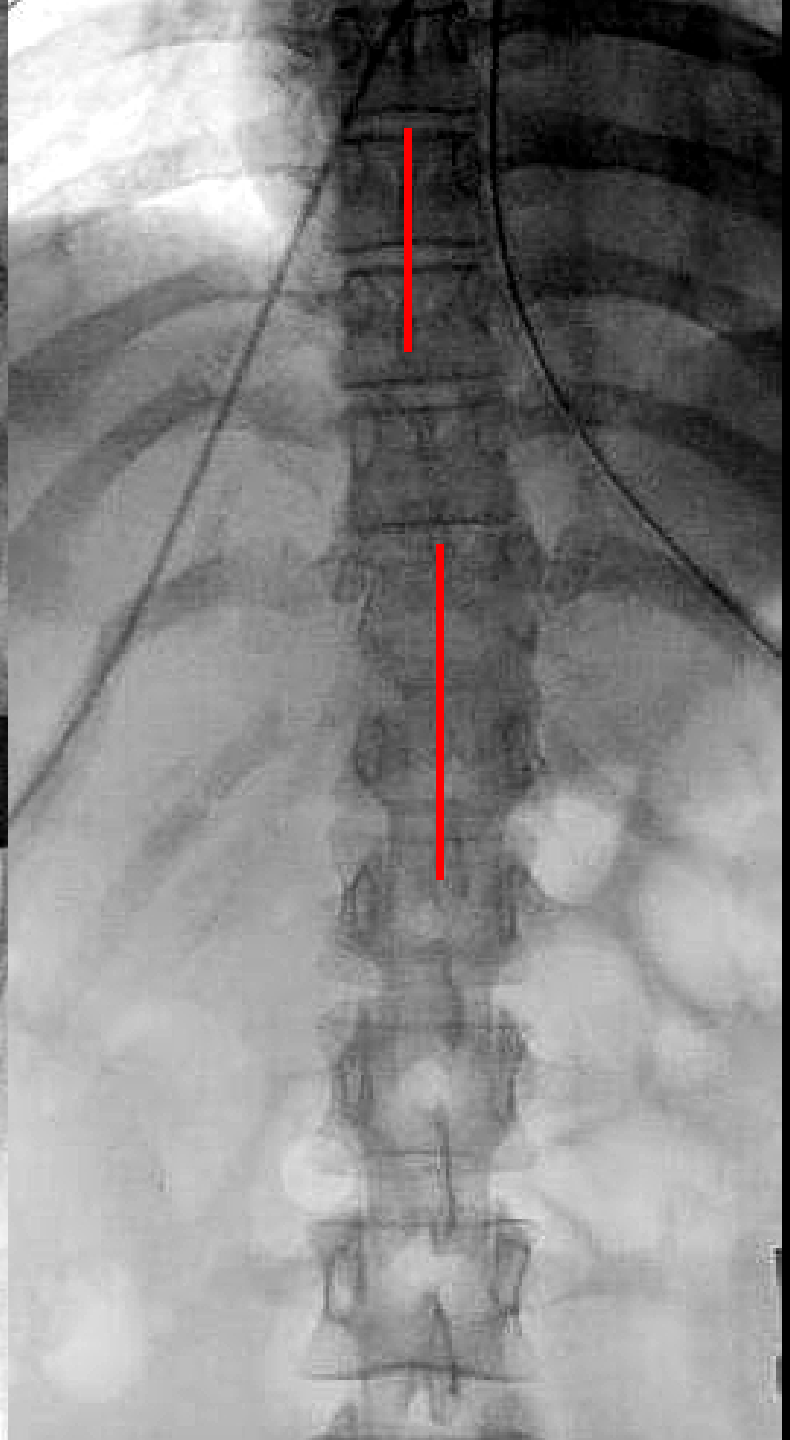

Fracture-Dislocation

TLICS :
morphology 3
PLC 3
neuro 2

TLICS = 8

Posterior segmental Fixation

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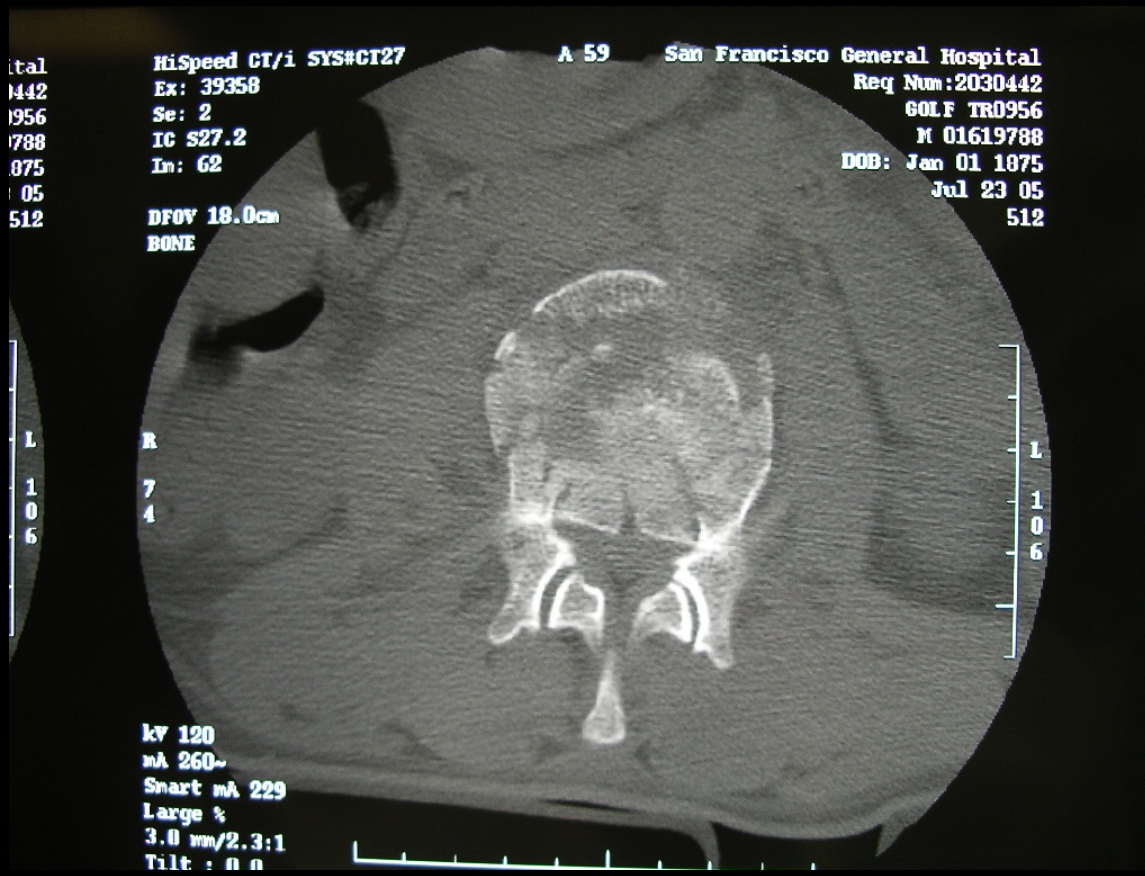
L3 Burst Fracture

TLICS : morphology 2, PLC 3, neuro 2 (root) = 7 = surgery



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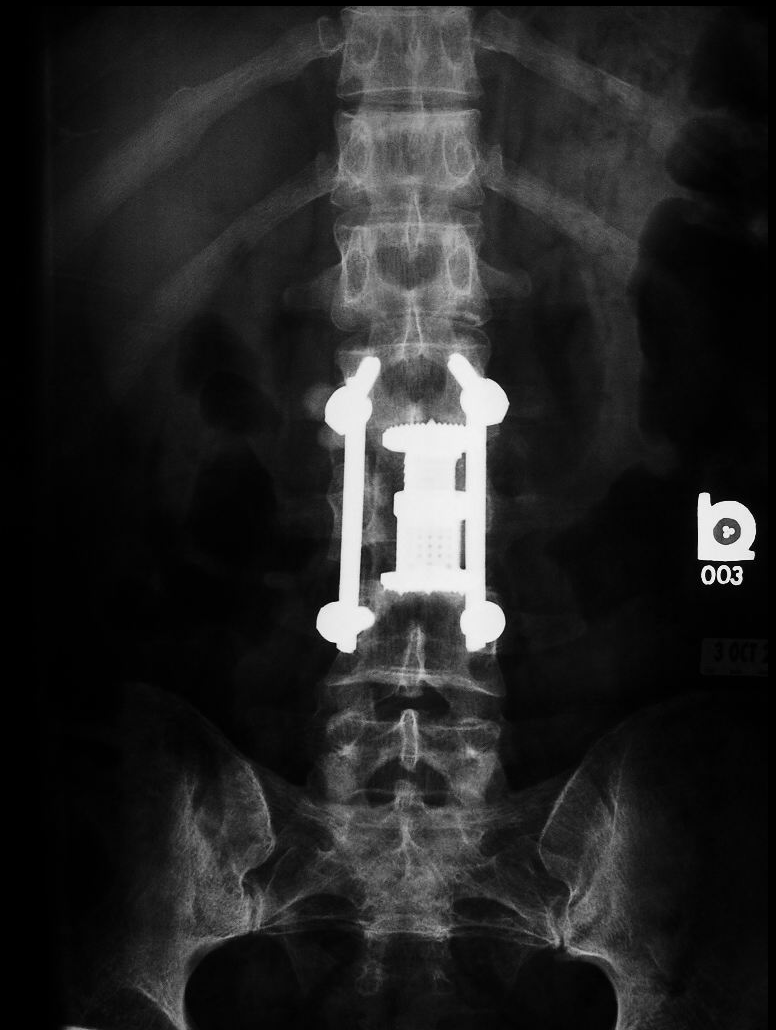
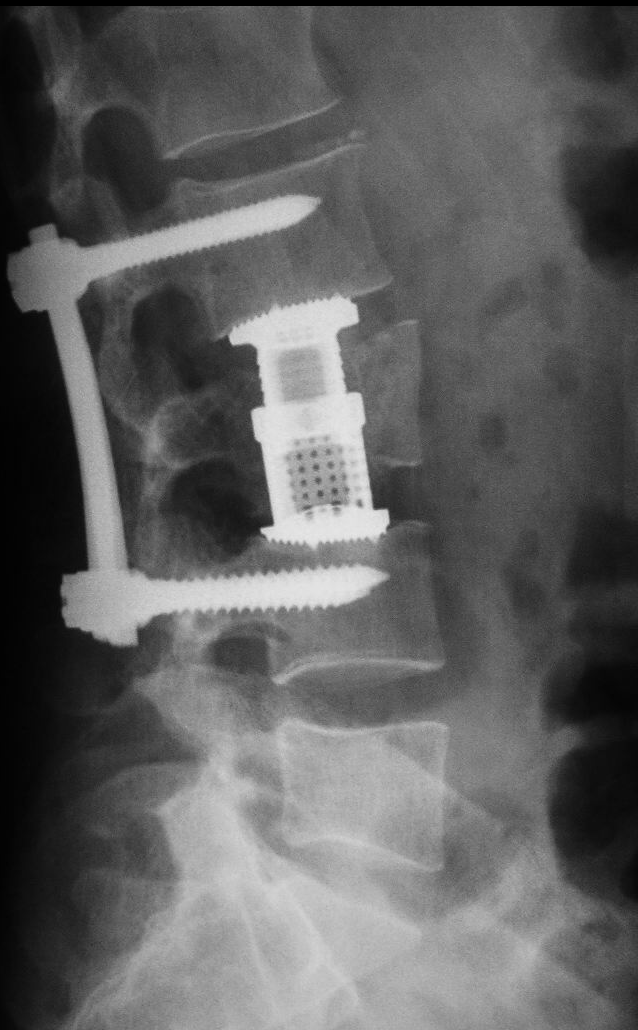
L3 Burst Fracture





Pathology of VCFs

- Vertebral compression fractures commonly occur as a result of minimal trauma from day-to-day activities, such as:
  - Bending forward
  - Lifting objects
  - Climbing stairs

Cooper C, et al. *J Bone Min Res*. 1992;7:221–227.
Frost HM. *Orthop Clin North Am*. 1981;12:671–681.
Parfitt AM, Duncan H. In: Rothman RH, Simeone FA, eds. *The Spine*. 2nd Edition. Philadelphia: WM Saunders;1982:775–905.

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Vertebral Compression Fractures (Osteoporosis)

700,000 VCFs per year in the U.S.

ONLY 1/3 are diagnosed

150,000 hospitalizations per year

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Risk Factors for Initial VCFs

Common risk factors

- Age[1]
- Low BMD[2]
- Osteoporosis[3,4]
- Steroid use (secondary osteoporosis)[5,6]
- Smoking[7]
- Other
  - Early menopause[6,8]
  - Unintentional weight loss or malnutrition[6]
  - Alcohol use[9]
  - Sedentary lifestyle[10]

1. O'Neill T, et al. *J Bone Miner Res*. 2002;17:2214-2221.
2. Marshall D, et al. *BMJ*. 1996;312:1254-1259.
3. Riggs BL, Melton LJ, 3rd. *Bone*. 1995. 17:505S-511S.
4. Nevitt MC, et al. *J Bone Miner Res.* 2005;20:131-140.
5. Kanis JA, et al. *J Bone Miner Res.* 2004;19:893-899.
6. Tannenbaum C, et al. *J Clin Endocrin Metab*. 2002;87:4431–4437.
7. Kanis JA, et al. Osteoporos Int. 2005;16:155-162.
8. van der Klift M, et al. *J Bone Miner Res*. 2004;19:1172-1780.
9. Kanis JA, et al. *Osteoporos Int*. 2005;16:737-742.
10. Heaney R. *Bone*. 1992;13:S23-S26.

Profound Impact of Radiographically Detected VCFs on QOL

- Study of 334 people 65 years of age assessed by radiographs and SF-12

Loss of QOL comparable to:

≥ 3 Radiographic VCFs =

- Stroke
- Cancer

Van Schoor NM, et al. *Osteoporos Int*. 2005;16:749-56

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Vertebral Fracture Risk Following Recent Fracture

Incidence of New Vertebral Fracture in Year Following Vertebral Fracture

20% of women will experience another fracture within the first year of a vertebral fracture

Lindsay R, et al. *JAMA Int.* 2001;285(3):320-323.

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Epidemiology of cervical radiculopathy "pinched nerve in the neck"

.

A population-based study from Rochester, Minnesota, 1976 - 1990

561 patients

Only 14.8 % had history of exertion or trauma

A confirmed disc protrusion was responsible for cervical radiculopathy in 21.9% of patients

Brain 1994
Radhakrishnan K[1], Litchy WJ, O'Fallon WM, Kurland LT

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Thank You

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