Approach to a patient with Spinal Trauma

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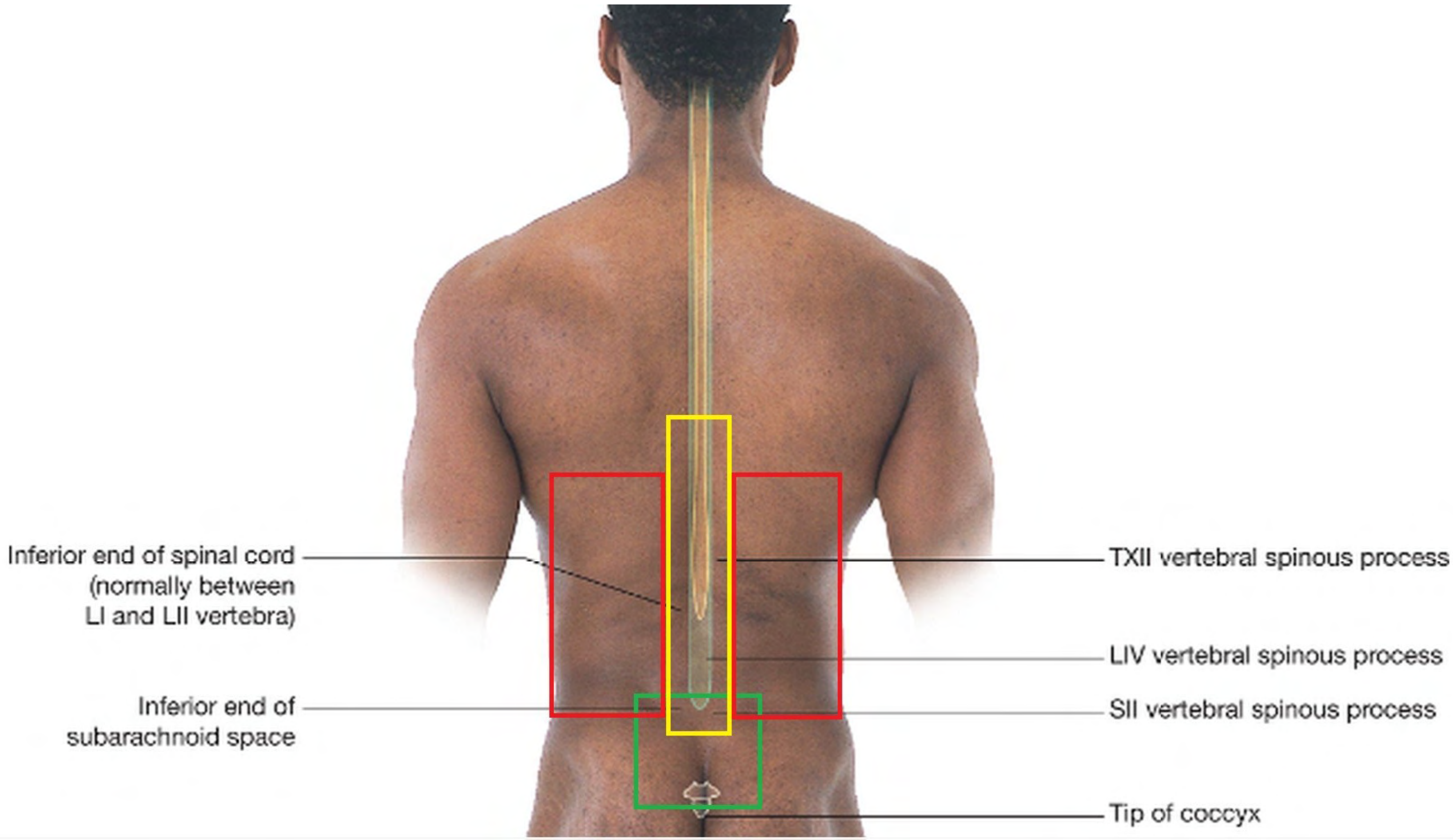
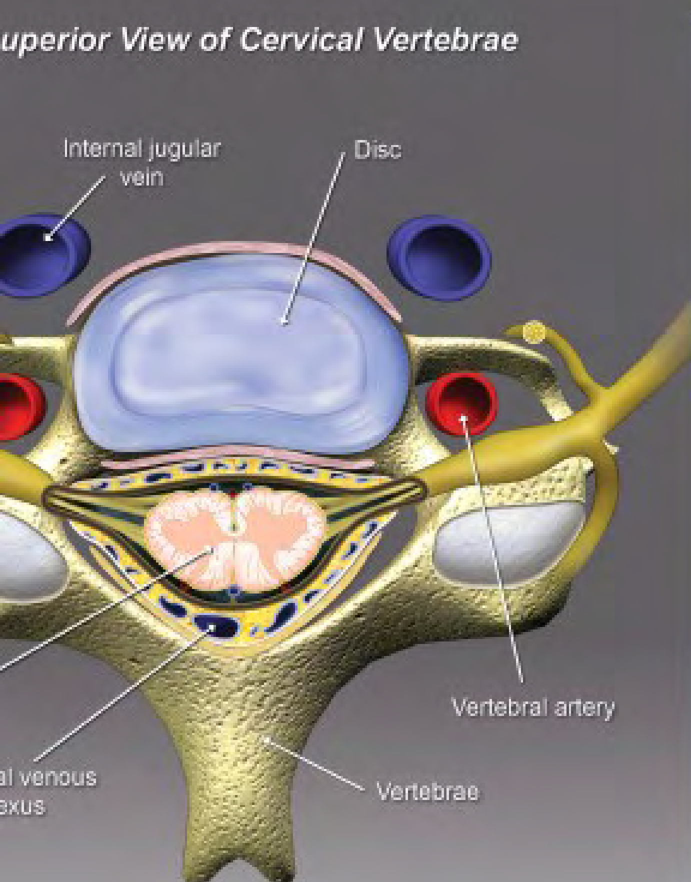
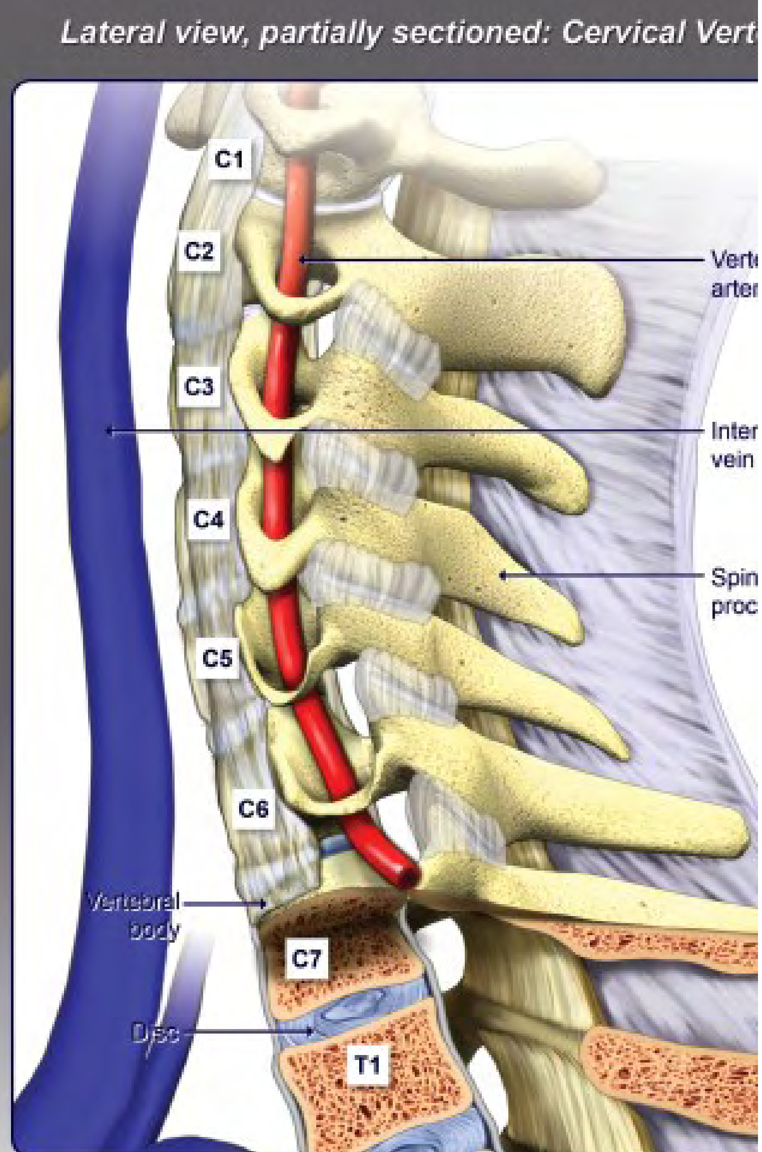
- Anatomy
- Clinical features
- Radiology
- Management
- Recent advances

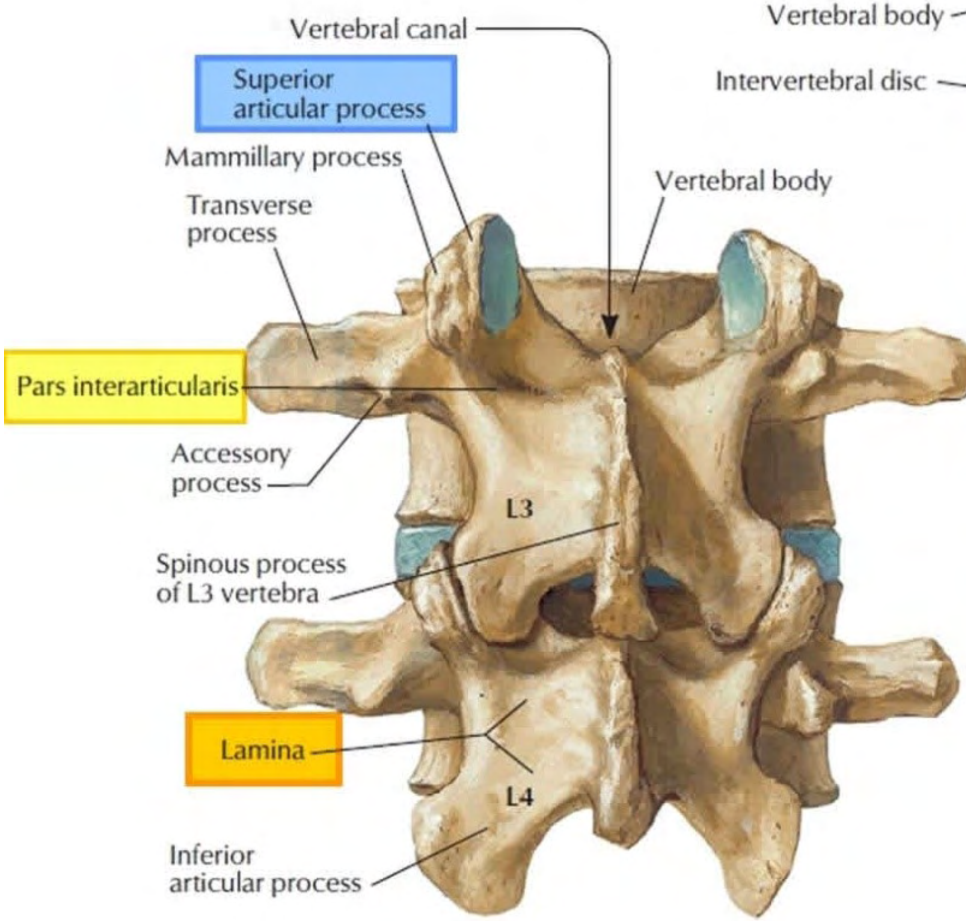
Anatomy


Inferior end of spinal cord
(normally between
LI and LII vertebra)
Inferior end of
subarachnoid space
TXII vertebral spinous process
LIV vertebral spinous process
SII vertebral spinous process
Tip of coccyx

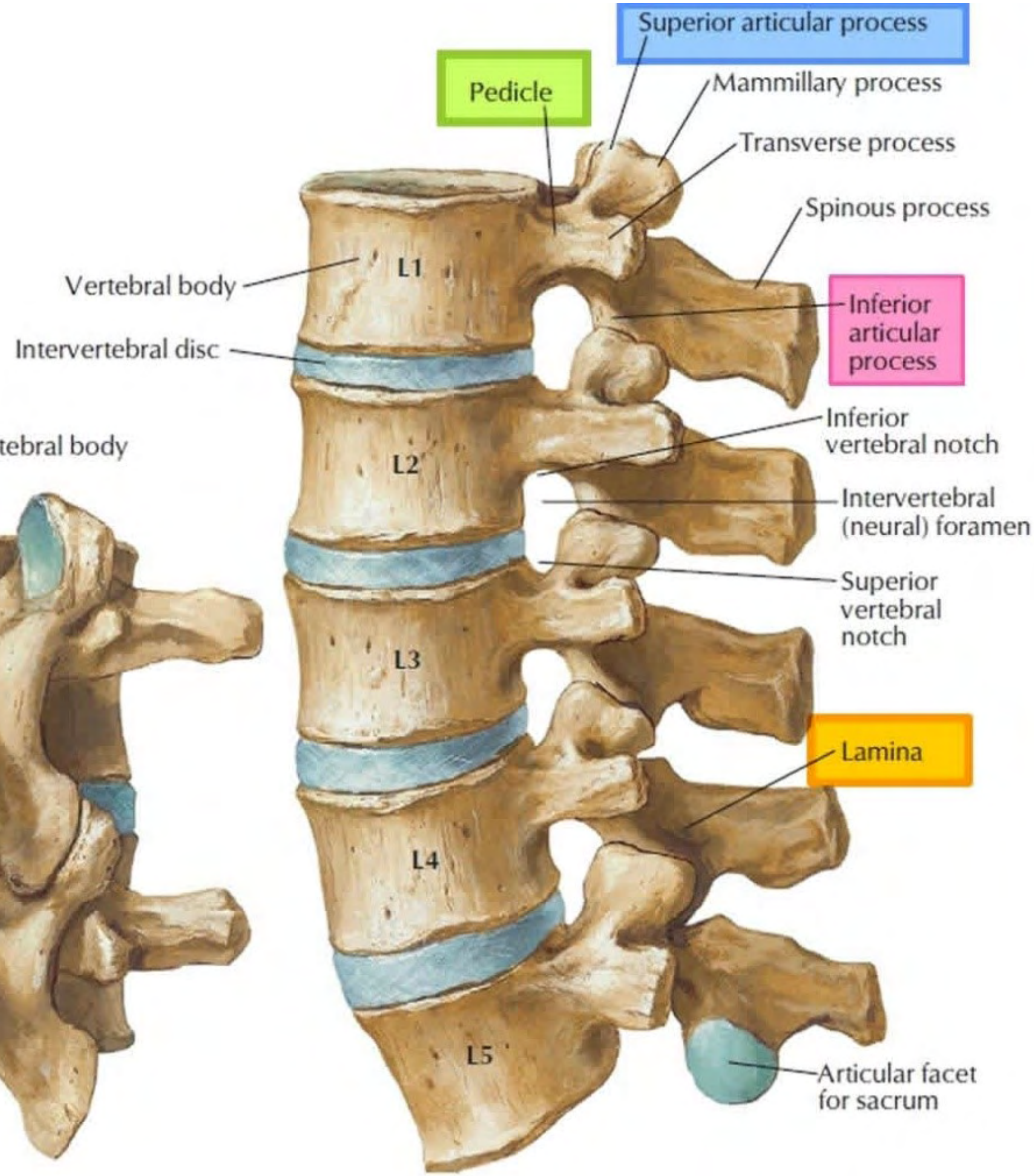
Anatomy of the Cervical Vertebra





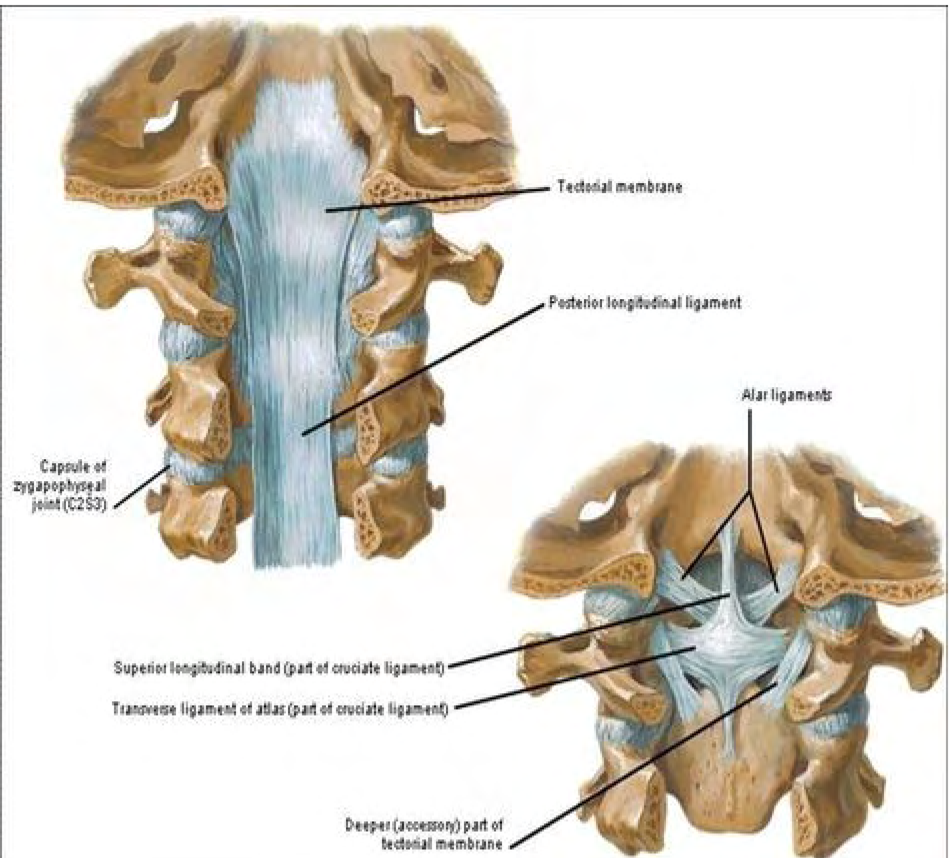


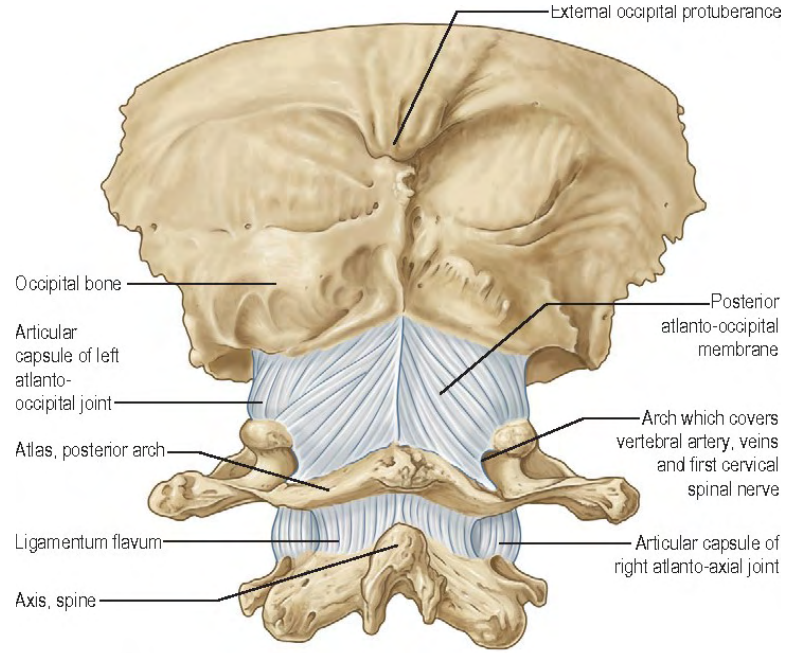
L3 and L4 vertebrae: posterior view

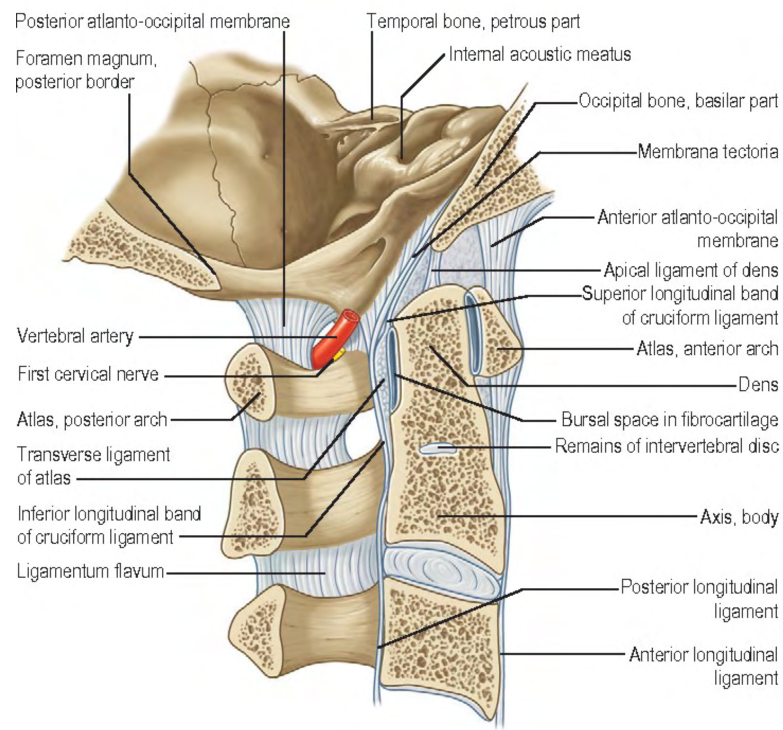


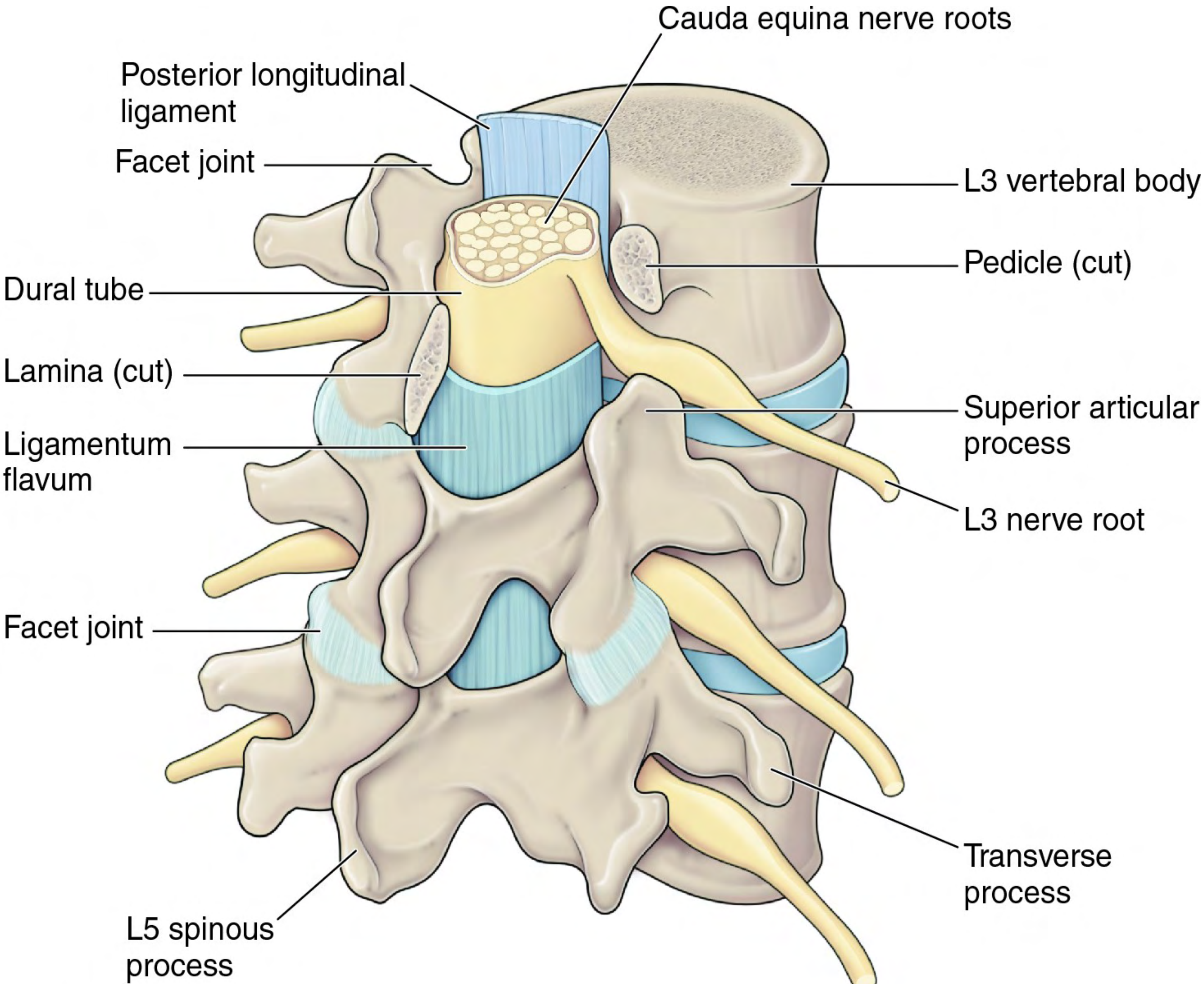
Lumbar vertebrae, articulated: left lateral view

Ligaments


Tectorial membrane
Posterior longitudinal ligament
Capsule of zygapophyseal joint (C2-3)
Alar ligaments
Superior longitudinal band (part of cruciate ligament)
Transverse ligament of atlas (part of cruciate ligament)
Deeper (accessory) part of tectorial membrane

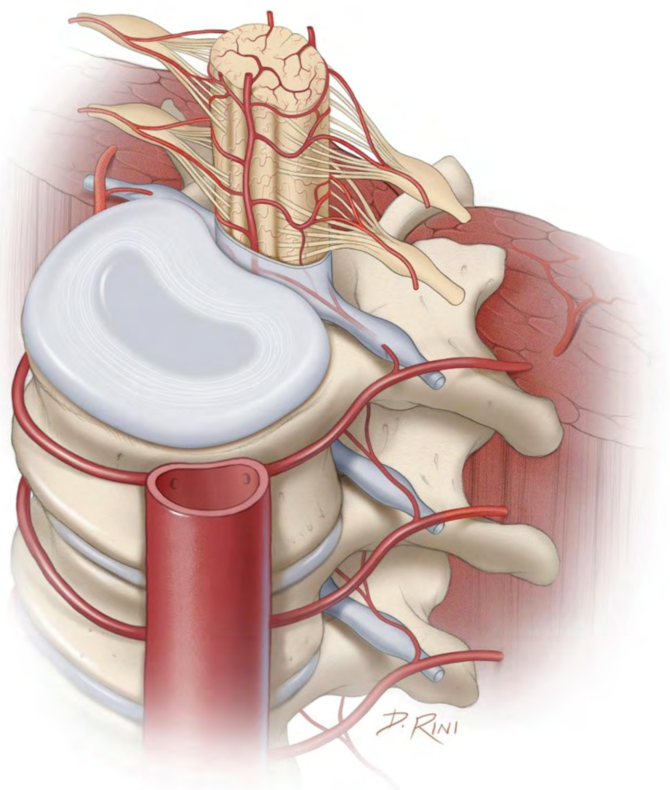

External occipital protuberance
Occipital bone
Posterior atlanto-occipital membrane
Articular capsule of left atlanto-occipital joint
Atlas, posterior arch
Arch which covers vertebral artery, veins and first cervical spinal nerve
Ligamentum flavum
Articular capsule of right atlanto-axial joint
Axis, spine

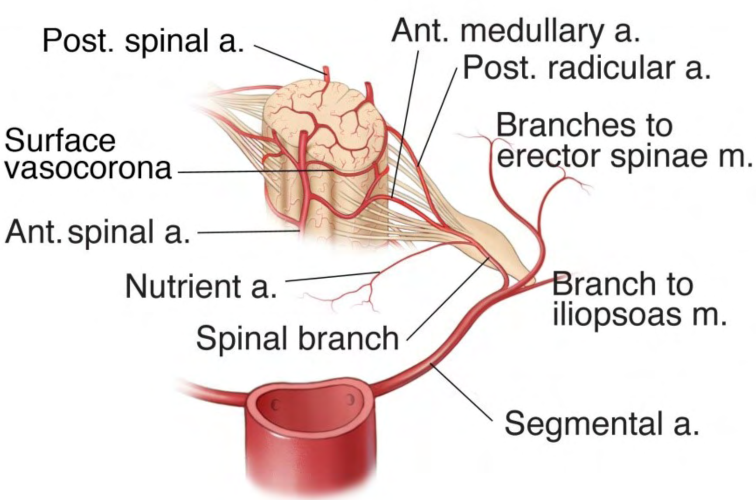

Posterior atlanto-occipital membrane
Temporal bone, petrous part
Foramen magnum, posterior border
Internal acoustic meatus
Occipital bone, basilar part
Membrana tectoria
Anterior atlanto-occipital membrane
Apical ligament of dens
Superior longitudinal band of cruciform ligament
Vertebral artery
Atlas, anterior arch
First cervical nerve
Dens
Atlas, posterior arch
Bursal space in fibrocartilage
Remains of intervertebral disc
Transverse ligament of atlas
Inferior longitudinal band of cruciform ligament
Axis, body
Ligamentum flavum
Posterior longitudinal ligament
Anterior longitudinal ligament

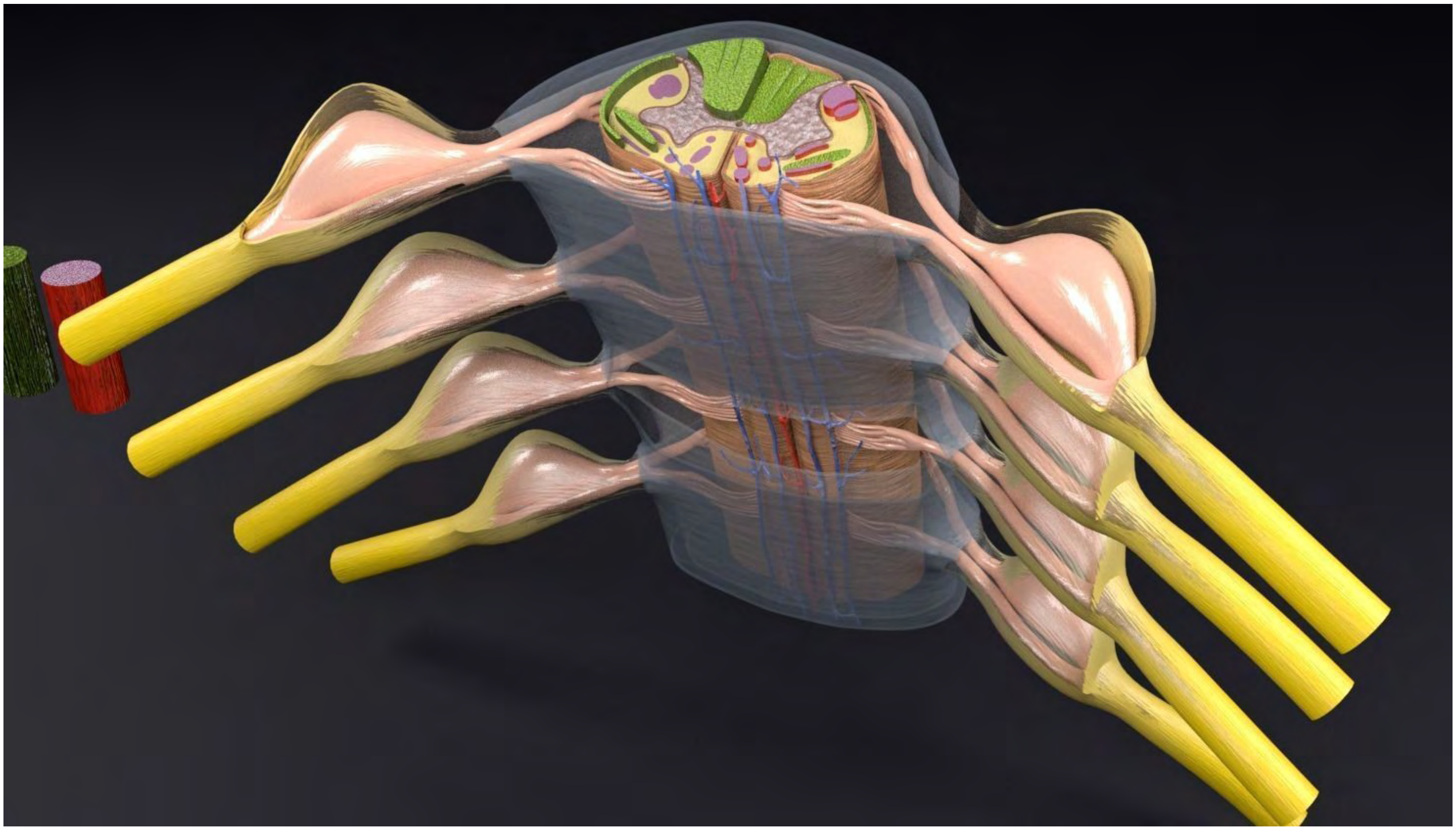


Cauda equina nerve roots
Posterior longitudinal ligament
Facet joint
L3 vertebral body
Pedicle (cut)
Dural tube
Lamina (cut)
Superior articular process
Ligamentum flavum
L3 nerve root
Facet joint
Transverse process
L5 spinous process

Anatomy


D. RINI


Post. spinal a.
Ant. medullary a.
Post. radicular a.
Branches to erector spinae m.
Surface vasocorona
Ant. spinal a.
Nutrient a.
Spinal branch
Branch to iliopsoas m.
Segmental a.



Spinal Cord Crossection: Detailed Anantomy

1 Fasciculus gracilis
1a Fasciculus cuneatus
} Dorsal columns

2 Dorsolateral fasciculus or tract of Lissauer

3 Posterior or dorsal spinocerebellar tract

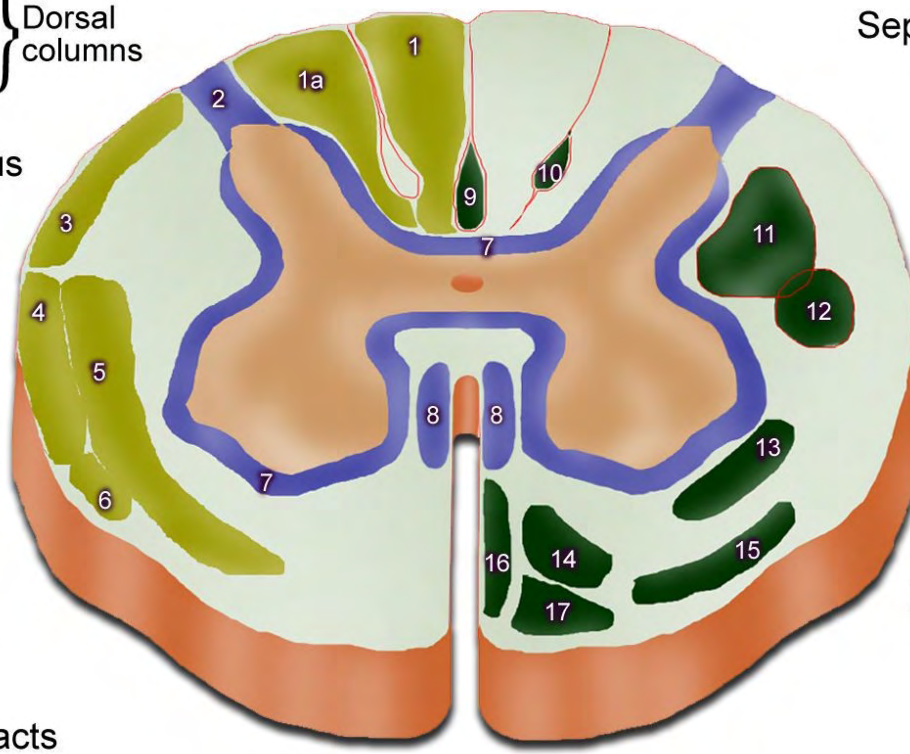
4 Anterior or ventral spinocerebellar tract

5 Spinothalamic, spinoreticular, spinomesencephalic (spinotectal), and spinohypothalamic tracts

6 Spinoolivary tract

7 Fasciculi proprii

8 Medial longtudinal or sulcomarginal fasciculi



Septomarginal fasciculus 9

Interfascicular or semilunar fasciculus 10

Lateral corticospinal or pyramidal 11

Rubrospinal tract 12

Medullary or lateral reticulospinal tract 13

Pontoreticulospinal or medial reticulospinal tract 14

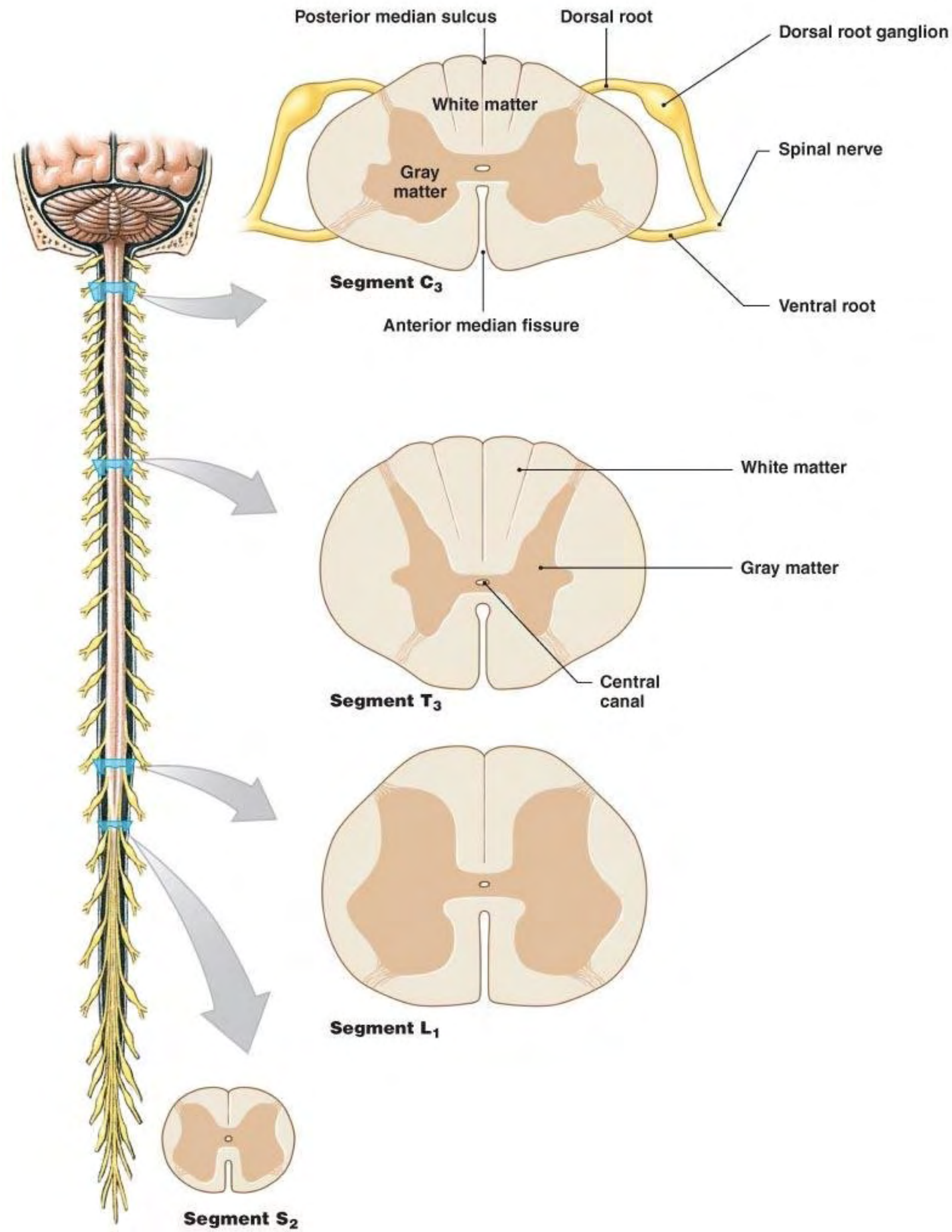
Vestibulospinal tract 15

Anterior or ventral corticospinal tract 16

Tectospinal tract 17

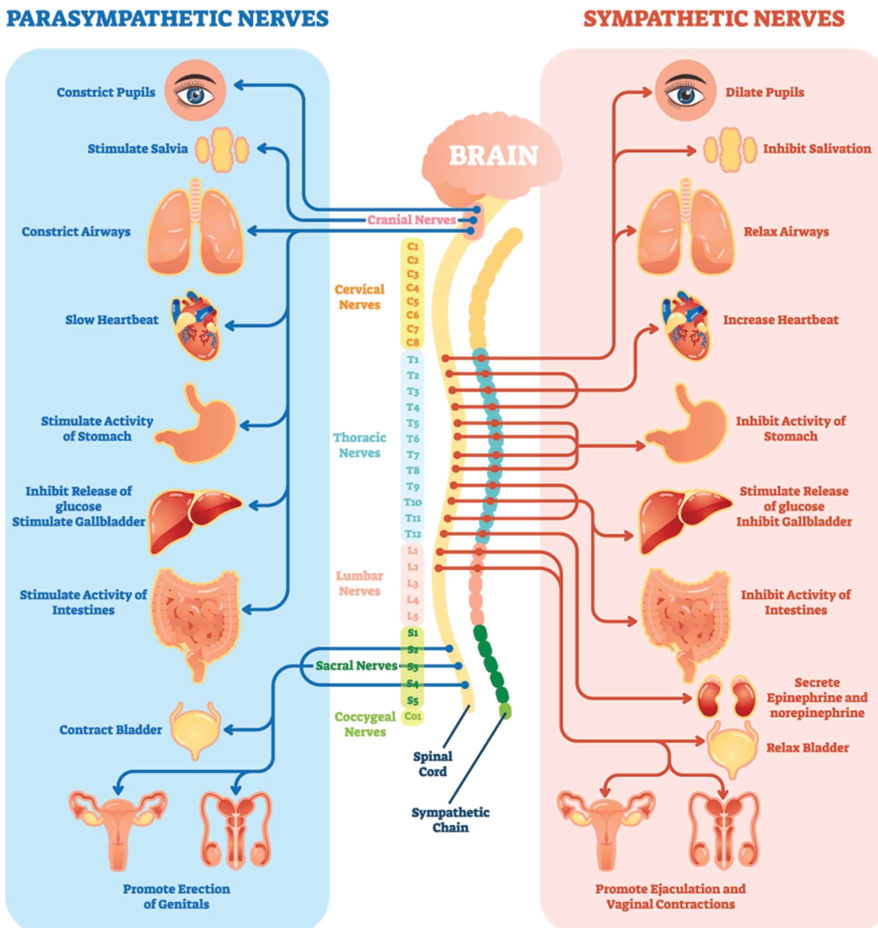
Ascending tracts
Decending tracts
Bidirectional tracts

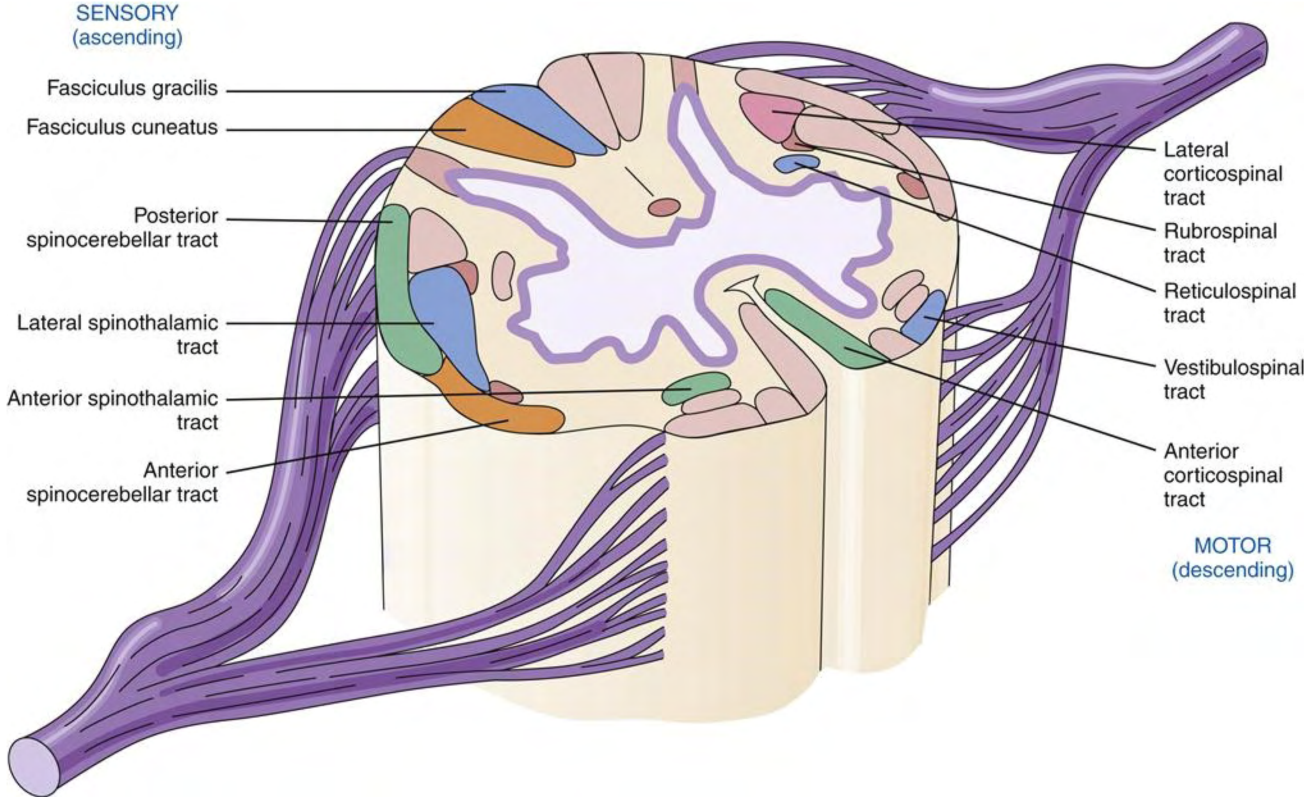
Tract at Risk



CS Tract
Spinothalamic tract
Dorsal coloumn
Autonomic System

Autonomic system

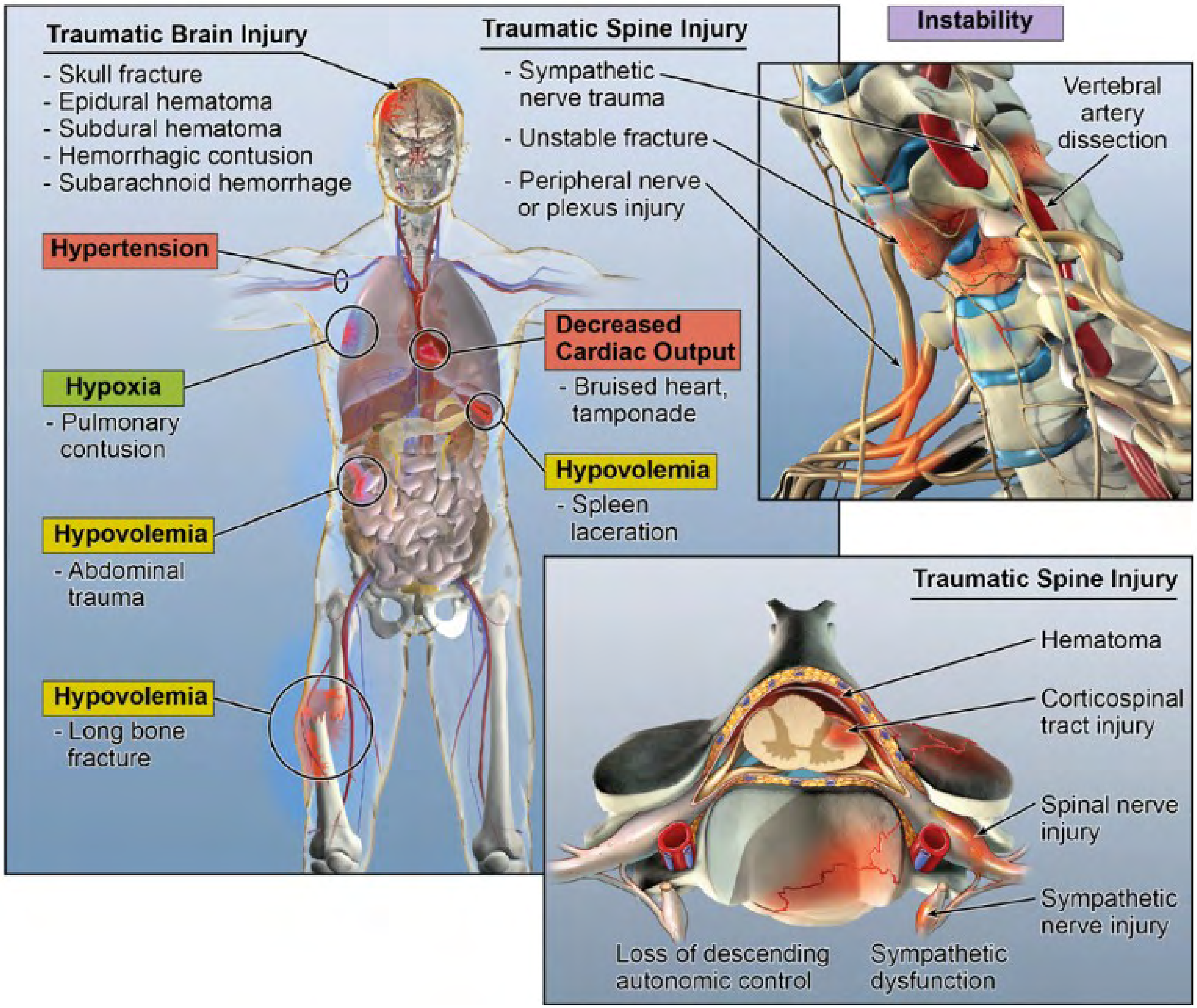



SENSORY
(ascending)
Fasciculus gracilis
Fasciculus cuneatus
Posterior spinocerebellar tract
Lateral spinothalamic tract
Anterior spinothalamic tract
Anterior spinocerebellar tract
Lateral corticospinal tract
Rubrospinal tract
Reticulospinal tract
Vestibulospinal tract
Anterior corticospinal tract
MOTOR
(descending)

SCI :Structures at risk

- Spinal Cord
- Vertebral column including Disc(CVJ to Sacrum)
- Ligaments and Muscles
- Nerve roots, Nerve
- Artery, vein
- PAN injury

SCI and Poly trauma



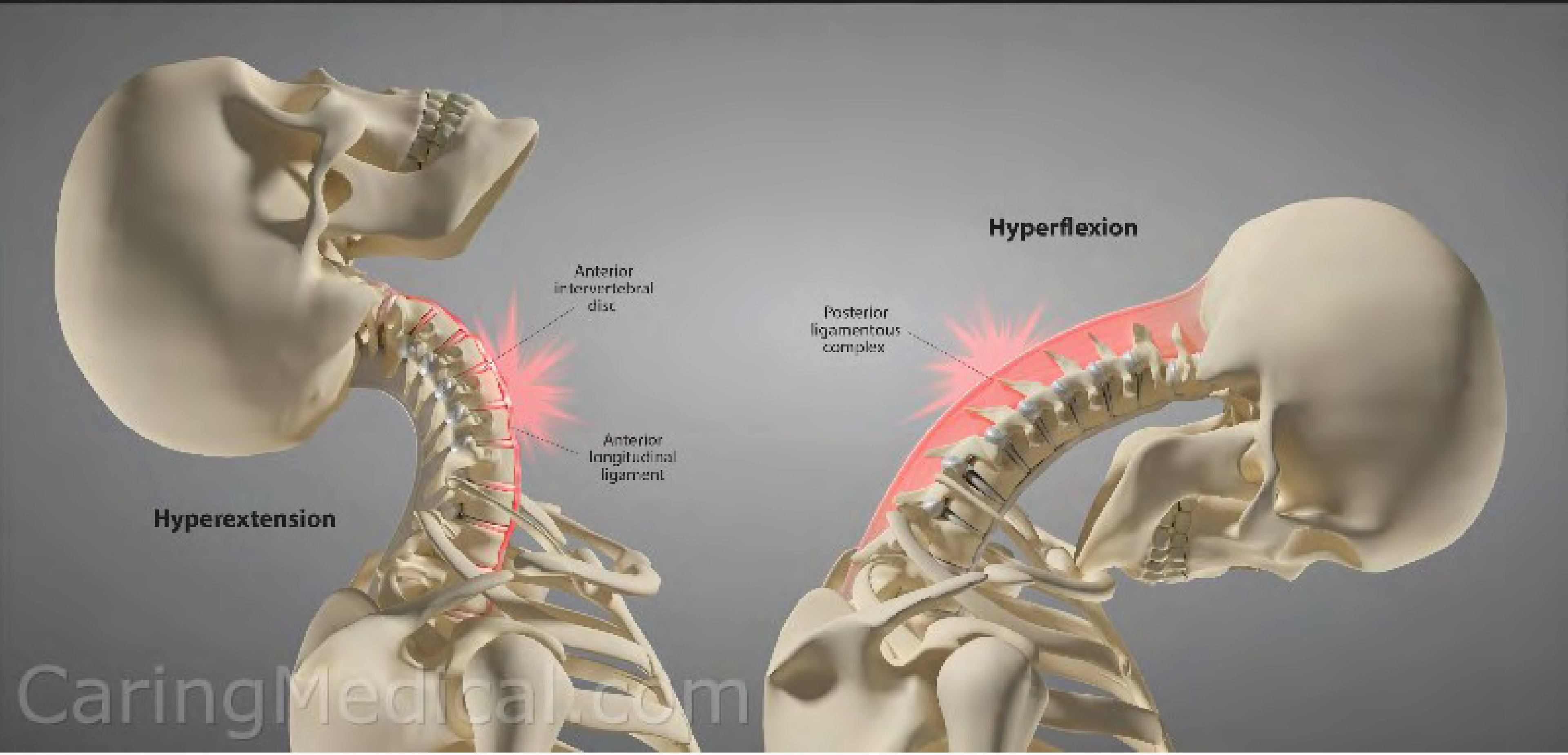
Mode of Injury

- Trauma (RSA,fall,assaults,sucide,fire arm etc)
- Non Traumatic (Osteoporotic bone..)

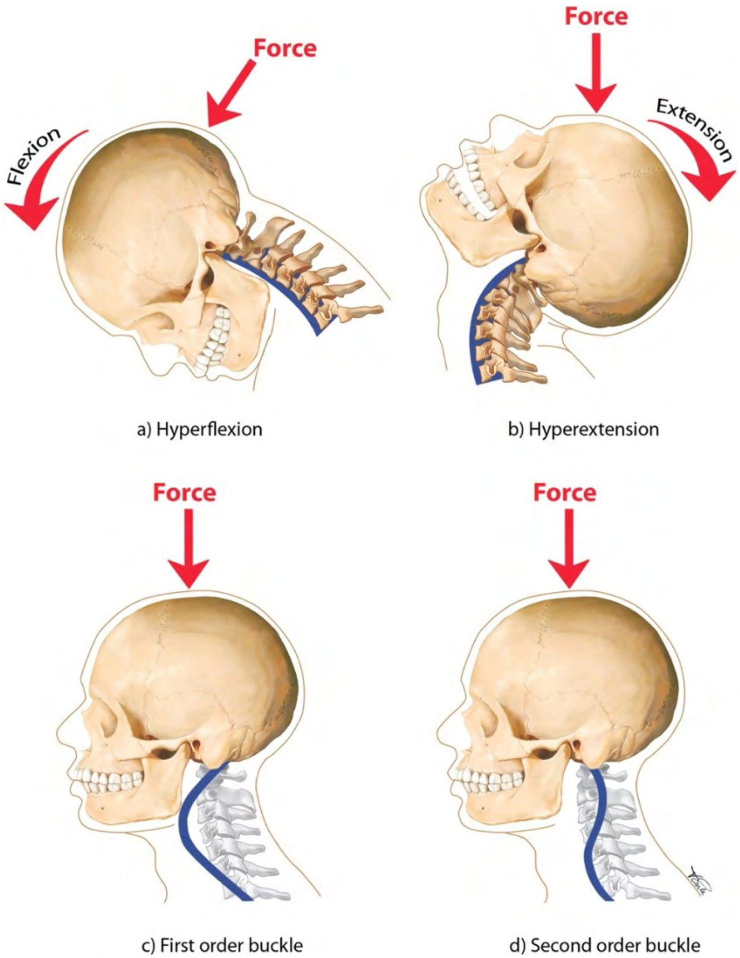
- Electrocution
- Fall of object on head/neck
- Wrestling

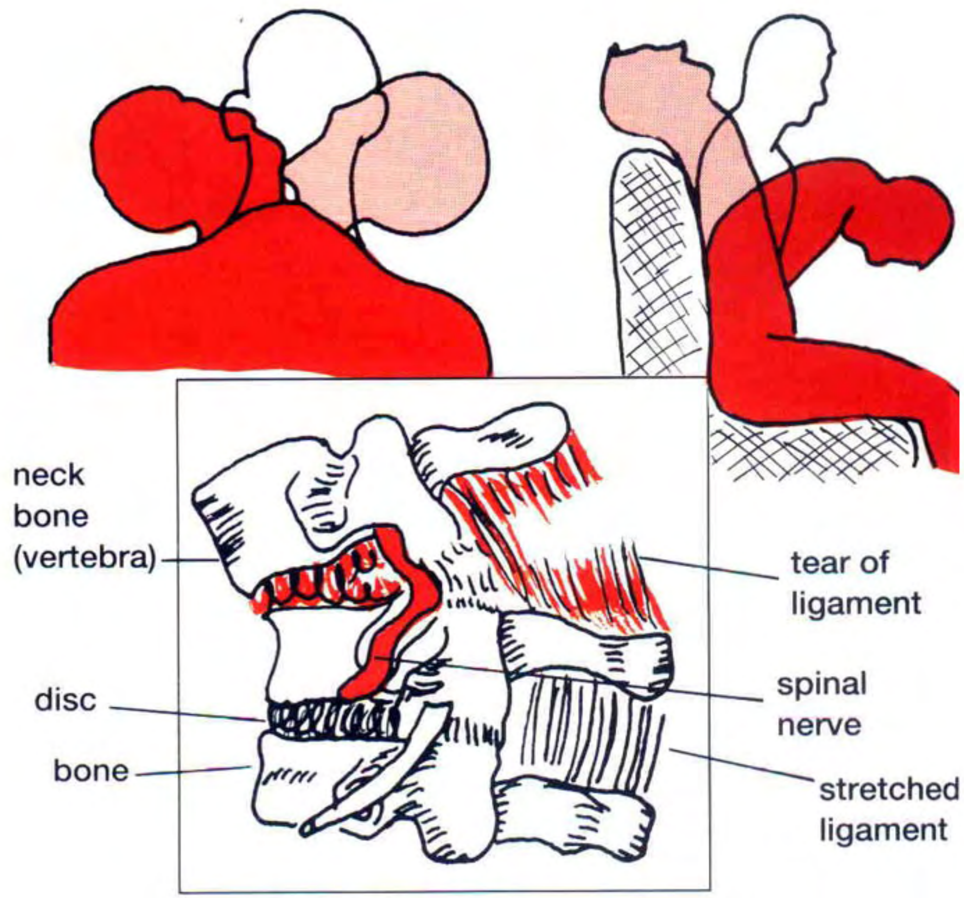
Mechanisms

Ligament strain with cervical extension and flexion during whiplash injury. Hyperflexion stretches the posterior ligamentous complex whereas hyperextension causes strain (stretch) on the anterior intervertebral disc and anterior longitudinal ligament.

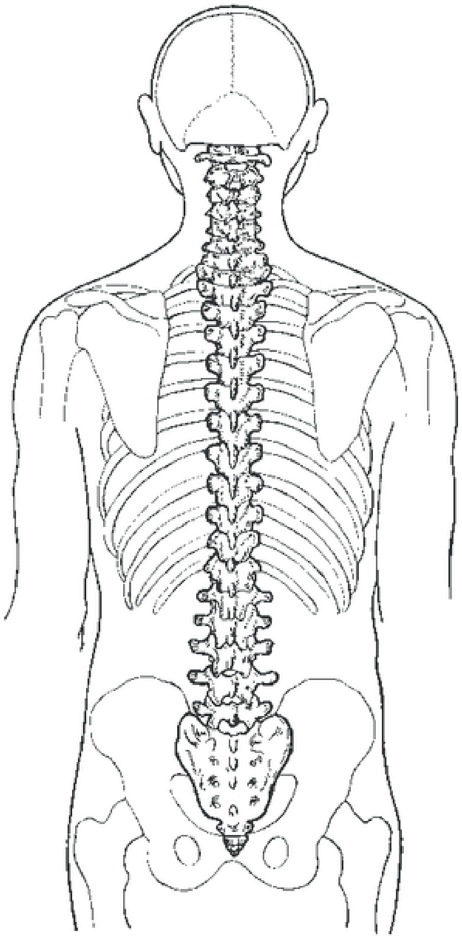


Mechanism


Force
Flexion
a) Hyperflexion
Force
Extension
b) Hyperextension
Force
c) First order buckle
Force
d) Second order buckle


neck
bone
(vertebra)
tear of
ligament
disc
spinal
nerve
bone
stretched
ligament

Cascade of Events



Primary Injury

Mechanical Injury

- Shearing and compression forces
- Vasculature disruptions
- Cell death

Disruptions

- Respiratory difficulties
- Neurogenic shock
- Inflammation
- Membrane compromise
- Alterations in ion and neurotransmitter levels

Secondary Injury

Ischemia

- Activation of the ischemic cascade
- Excessive Ca^{2+} and ROS production
- Apoptosis

Inflammation

- Astrogliosis
- Lymphocyte infiltration of lesion
- Activated and phagocytic monocytes

Excitotoxicity

- Excessive Ca^{2+} leading to ROS production and oxidative stress
- Excessive glutamate
- Apoptosis

SCI is a dynamic process:

BioMed Research International

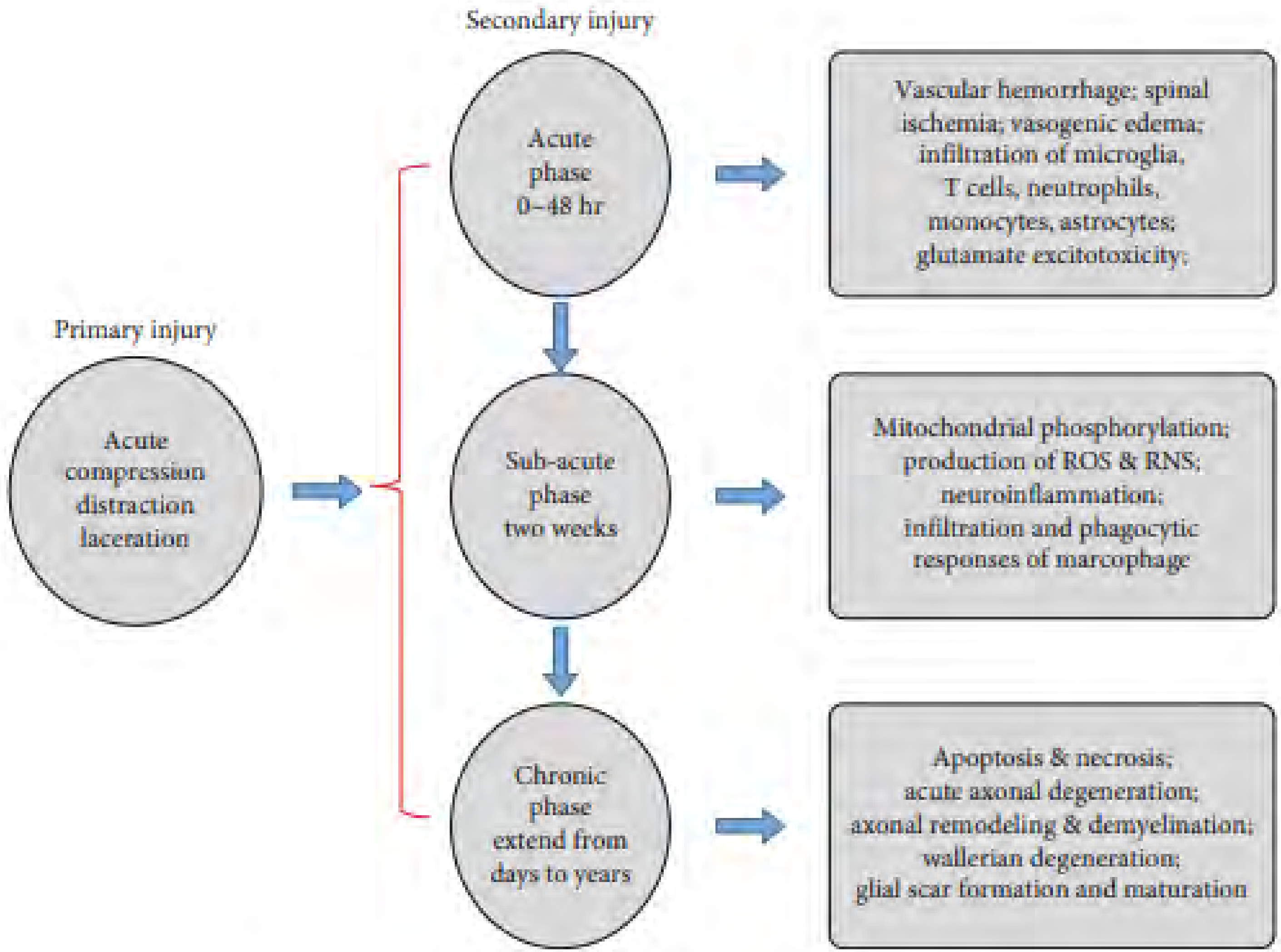
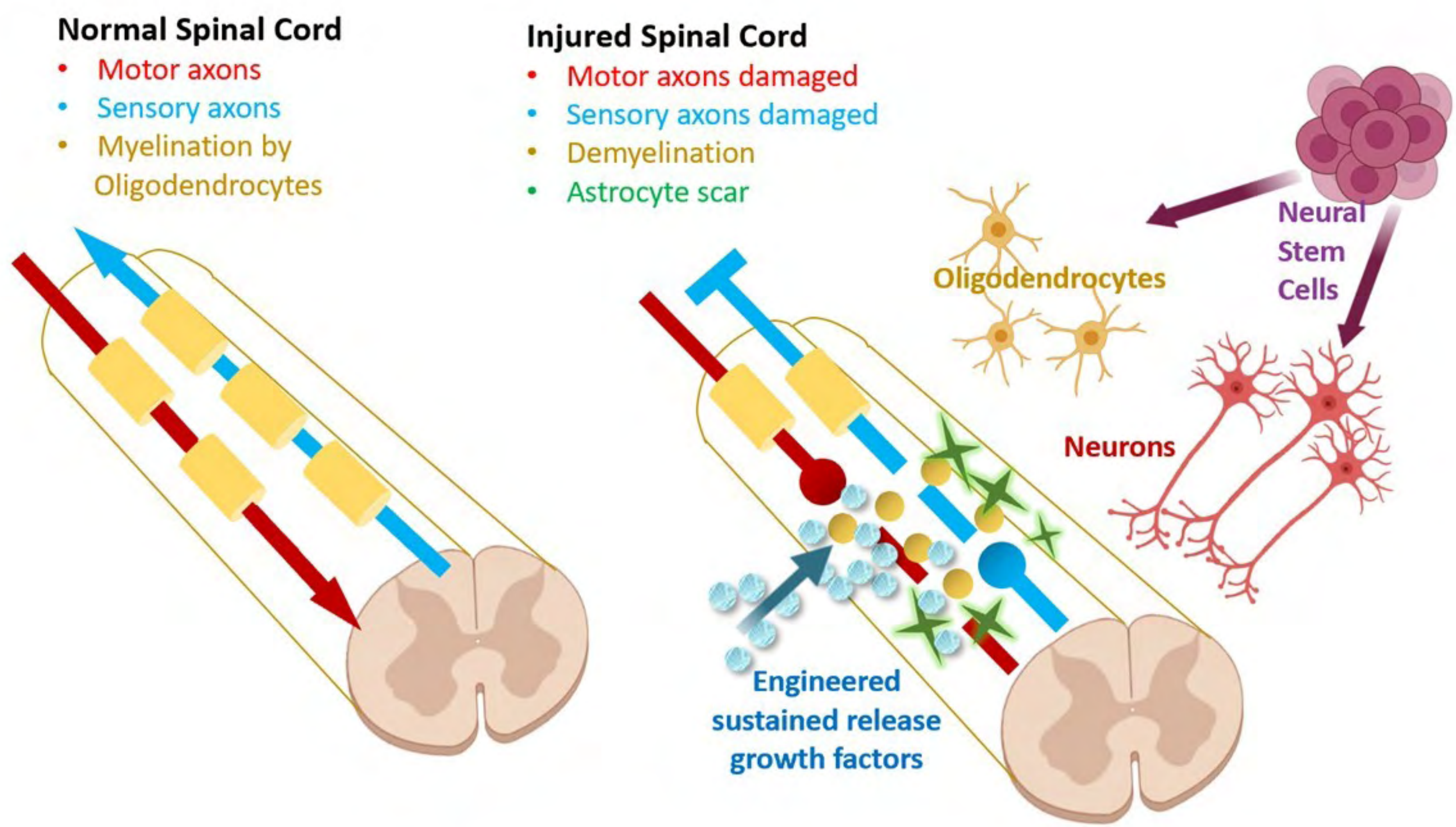


Figure 1: The mechanism of pathophysiological changes after SCI.


Normal Spinal Cord
• Motor axons
• Sensory axons
• Myelination by Oligodendrocytes
Injured Spinal Cord
• Motor axons damaged
• Sensory axons damaged
• Demyelination
• Astrocyte scar
Neural Stem Cells
Oligodendrocytes
Neurons
Engineered sustained release growth factors

CLINICAL SUSPICIONS

- Pain , tenderness
- Neurological Deficits
  - Weakness limb
  - Bladder Bowel
  - Autonomic dysfunction

❖ Complete injury
❖ Incomplete injury
❖ Grading of Injury

Localisation of Site

- Spinal cord (CVJ, Cx spine, Subcervical,...)
- Brachial Plexus : often missed due to ignorance
- Lumbar Plexus : Uncommon

Examination in Emergency/Casualty

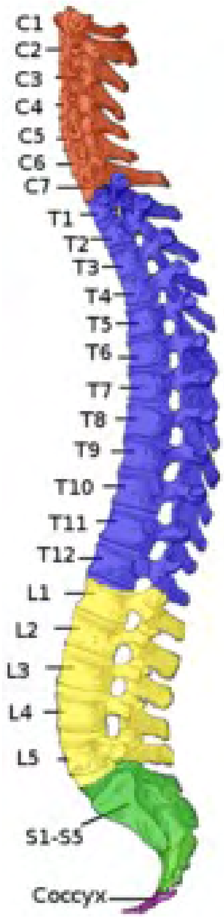
- Conscious Patient : Ask to move all limbs, Sensations , Feeling of pain, touch sensations
- Unconscious patient : Plantar, DT Reflexes, response to pain on limb
- With or without head trauma or Poly trauma

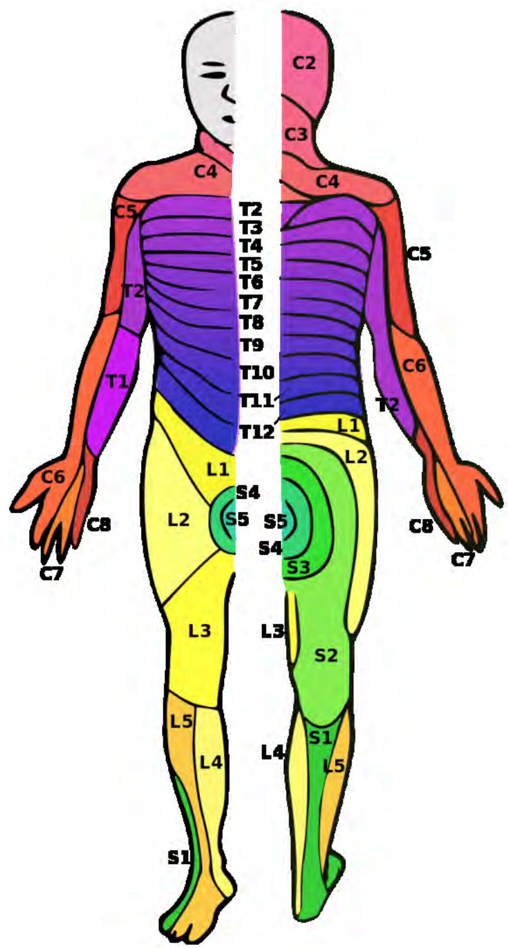
- Non movement of any one limb one should also suspect Brachial plexus injury , Lumbar plexus injury in addition to local bone fracture

- Black eye: try to see vision asap…

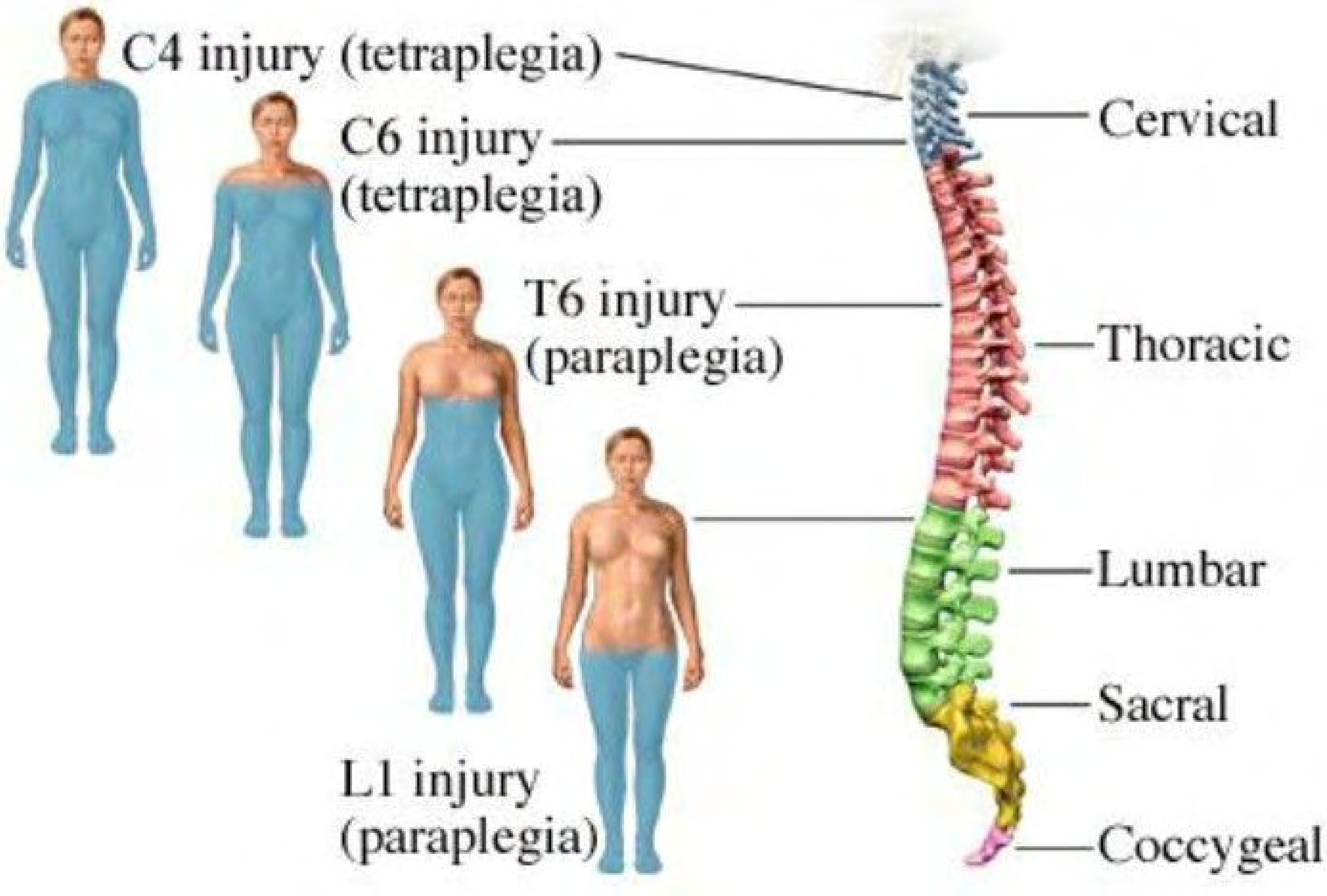
Neurogenic vs Spinal shock

- Neurogenic shock: hemodynamic changes with hypotension and bradycardia related to its injury.
- Spinal shock :Changes with sensation, motor, and reflexes.
- Spinal cord injuries above T6, neurogenic shock may occur,

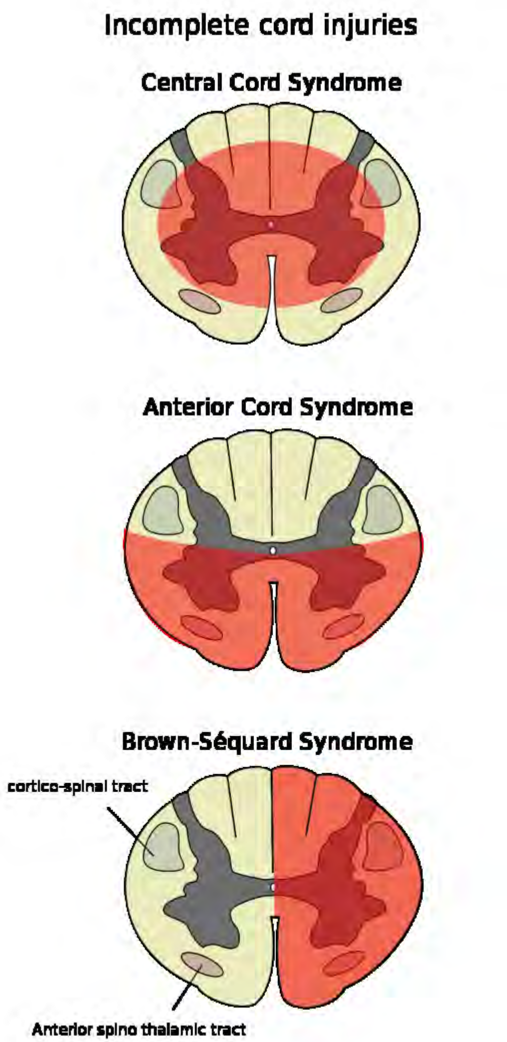




Level	Motor Function
C1–C6	Neck flexors
C1–T1	Neck extensors
C3, C4, C5	Supply diaphragm (mostly C4)
C5, C6	Move shoulder, raise arm (deltoid); flex elbow (biceps)
C6	externally rotate (supinate) the arm
C6, C7	Extend elbow and wrist (triceps and wrist extensors); pronate wrist
C7, T1	Flex wrist; supply small muscles of the hand
T1–T6	Intercostals and trunk above the waist
T7–L1	Abdominal muscles
L1–L4	Flex thigh
L2, L3, L4	Adduct thigh; Extend leg at the knee (quadriceps femoris)
L4, L5, S1	abduct thigh; Flex leg at the knee (hamstrings); Dorsiflex foot (tibialis anterior); Extend toes
L5, S1, S2	Extend leg at the hip (gluteus maximus); Plantar flex foot and flex toes


C4 injury (tetraplegia)
C6 injury
(tetraplegia)
T6 injury
(paraplegia)
L1 injury
(paraplegia)
Cervical
Thoracic
Lumbar
Sacral
Coccygeal

Clinical Syndromes



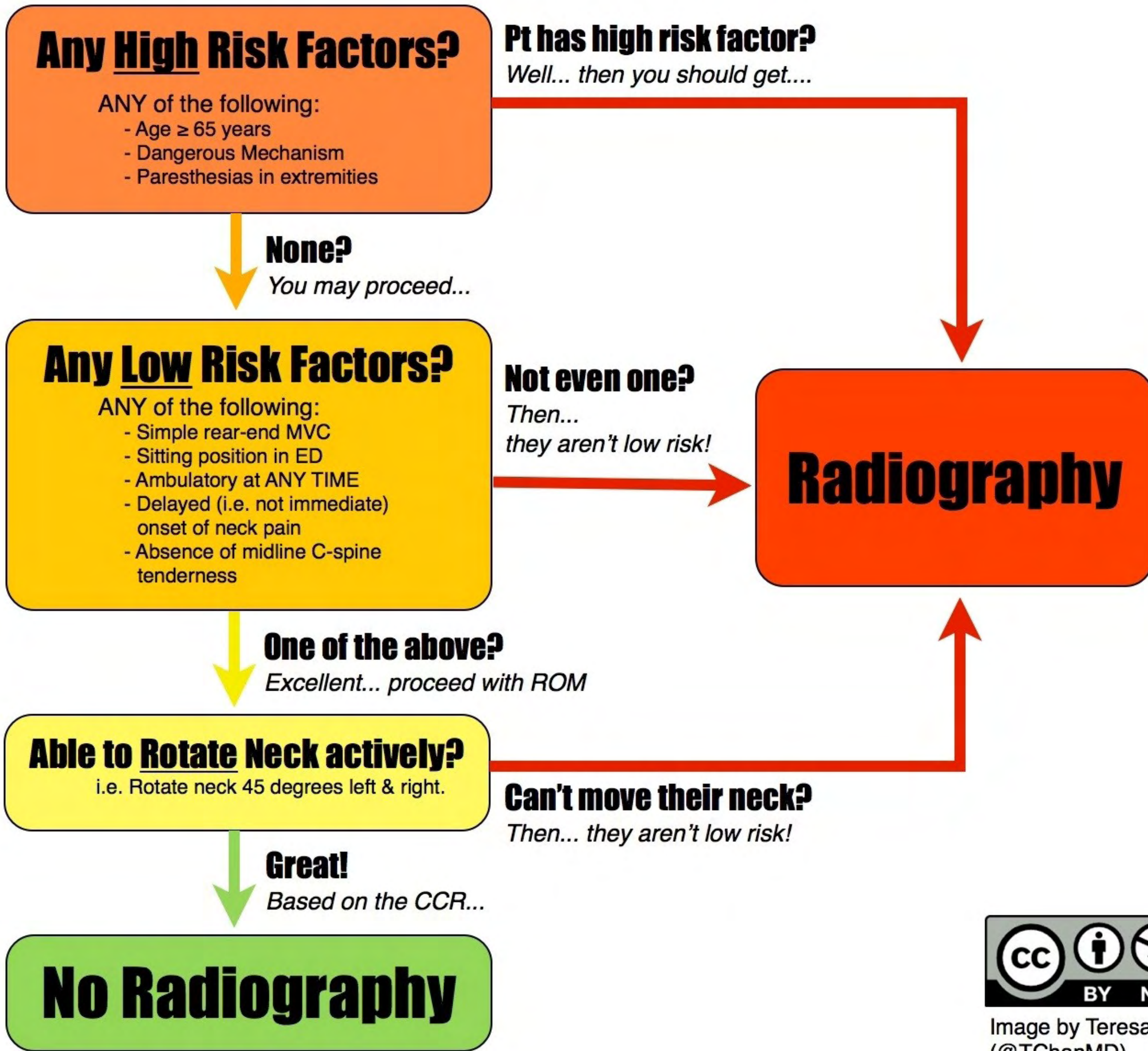
Anterior Cord Syndrome
Posterior Cord Syndrome
Central Cord Syndrome
Brown Sequard Syndrome
Conus Medularis Syndrome
Cauda Equina Syndrome

ASIA Score

Muscle strength[15]		ASIA Impairment Scale for classifying spinal cord injury[13][16]	
Grade	**Muscle function**	**Grade**	**Description**
0	No muscle contraction	**A**	**Complete injury**. No motor or sensory function is preserved in the sacral segments S4 or S5.
1	Muscle flickers	**B**	**Sensory incomplete**. Sensory but not motor function is preserved below the level of injury, including the sacral segments.
2	Full range of motion, gravity eliminated	**C**	**Motor incomplete**. Motor function is preserved below the level of injury, and more than half of muscles tested below the level of injury have a muscle grade less than 3 (see muscle strength scores, left).
3	Full range of motion, against gravity	**D**	**Motor incomplete**. Motor function is preserved below the level of injury and at least half of the key muscles below the neurological level have a muscle grade of 3 or more.
4	Full range of motion against resistance	**E**	**Normal**. No motor or sensory deficits, but deficits existed in the past.
5	Normal strength		

- Canadian C-Spine Rule (CCR)

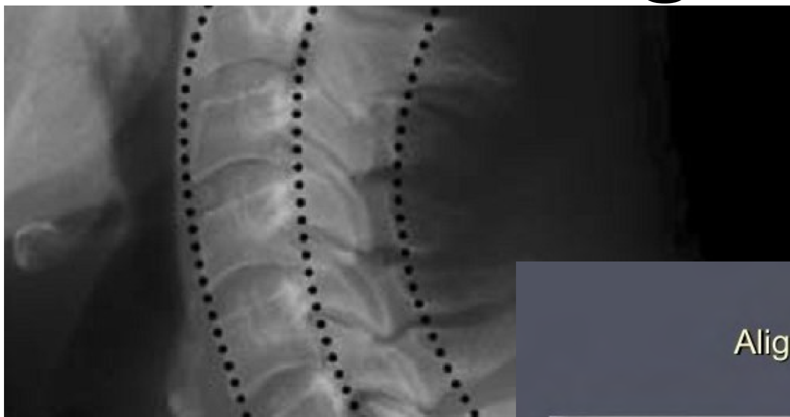
- National Emergency X-Radiography Utilization Study **Low-Risk Criteria** (NEXUS criteria) are clinical decision tools developed to help us decide when blunt trauma patients require C-spine X-ray.

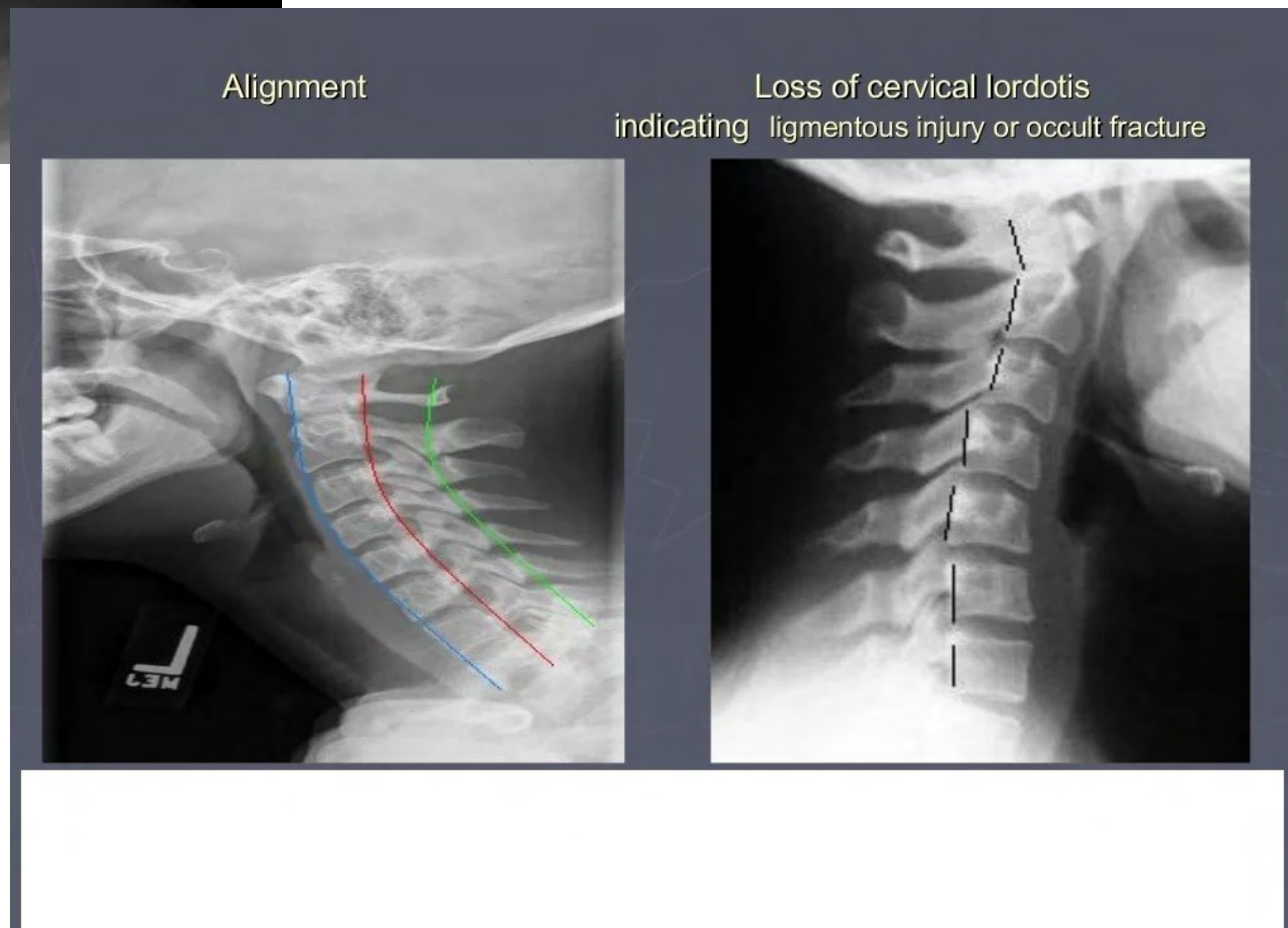

Any High Risk Factors?
ANY of the following:
- Age ≥ 65 years
- Dangerous Mechanism
- Paresthesias in extremities
Pt has high risk factor?
Well... then you should get....
None?
You may proceed...
Any Low Risk Factors?
ANY of the following:
- Simple rear-end MVC
- Sitting position in ED
- Ambulatory at ANY TIME
- Delayed (i.e. not immediate) onset of neck pain
- Absence of midline C-spine tenderness
Not even one?
Then...
they aren't low risk!
Radiography
One of the above?
Excellent... proceed with ROM
Able to Rotate Neck actively?
i.e. Rotate neck 45 degrees left & right.
Can't move their neck?
Then... they aren't low risk!
Great!
Based on the CCR...
No Radiography

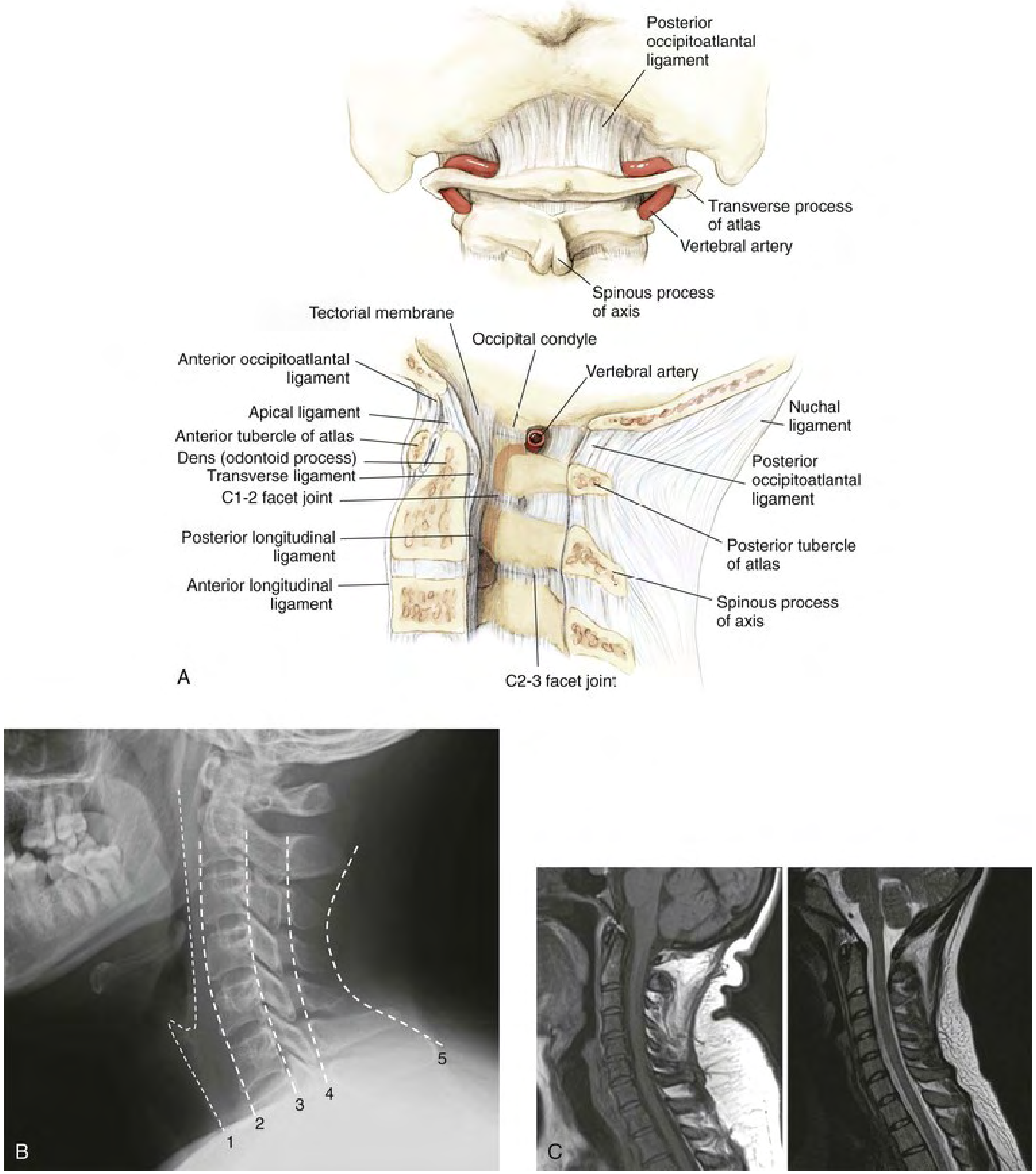
Canadian C-spine rules

- are a set of guidelines that help a clinician decide if cervical spine imaging is not appropriate for a trauma patient in the emergency department. The patient must be alert and stable.
- There are three rules:
- is there any **high-risk** factor present that requires cervical spine imaging?
  - ≥65 years
  - a dangerous mechanism
    - fall from elevation >3 ft (or 5 stairs)
    - axial load to the head
    - high-speed motor vehicle collision (e.g. >100 km/hr or ~60 mph, rollover, ejection)
    - motorized recreational vehicles
    - bicycle collision
  - paresthesias in extremities
- If any high-risk factor is present, then cervical spine imaging is warranted.
- is there any **low-risk** factor present?
  - simple rear-end motor vehicle collision
    - excludes being hit by a high-speed vehicle, a large vehicle (e.g. bus), or rollover
  - sitting position in emergency department
  - ambulatory at any time since the injury
  - delayed onset of neck pain
  - absence of midline C-spine tenderness
- If the patient does not meet the criteria of a low-risk injury, then cervical spine imaging is warranted.
- If the patient meets the criteria of a low-risk injury, then one should assess on physical exam whether the patient can rotate the neck 45°.
- if low-risk injury and the patient can rotate the neck 45°
  - no cervical spine imaging required
- if low-risk injury and the patient cannot rotate the neck 45°
  - then cervical spine imaging is warranted
- The original study presented 100% sensitivity for identifying "clinically important C-spine injuries" (95 percent confidence interval 98%-100%).

Radiological Assessments



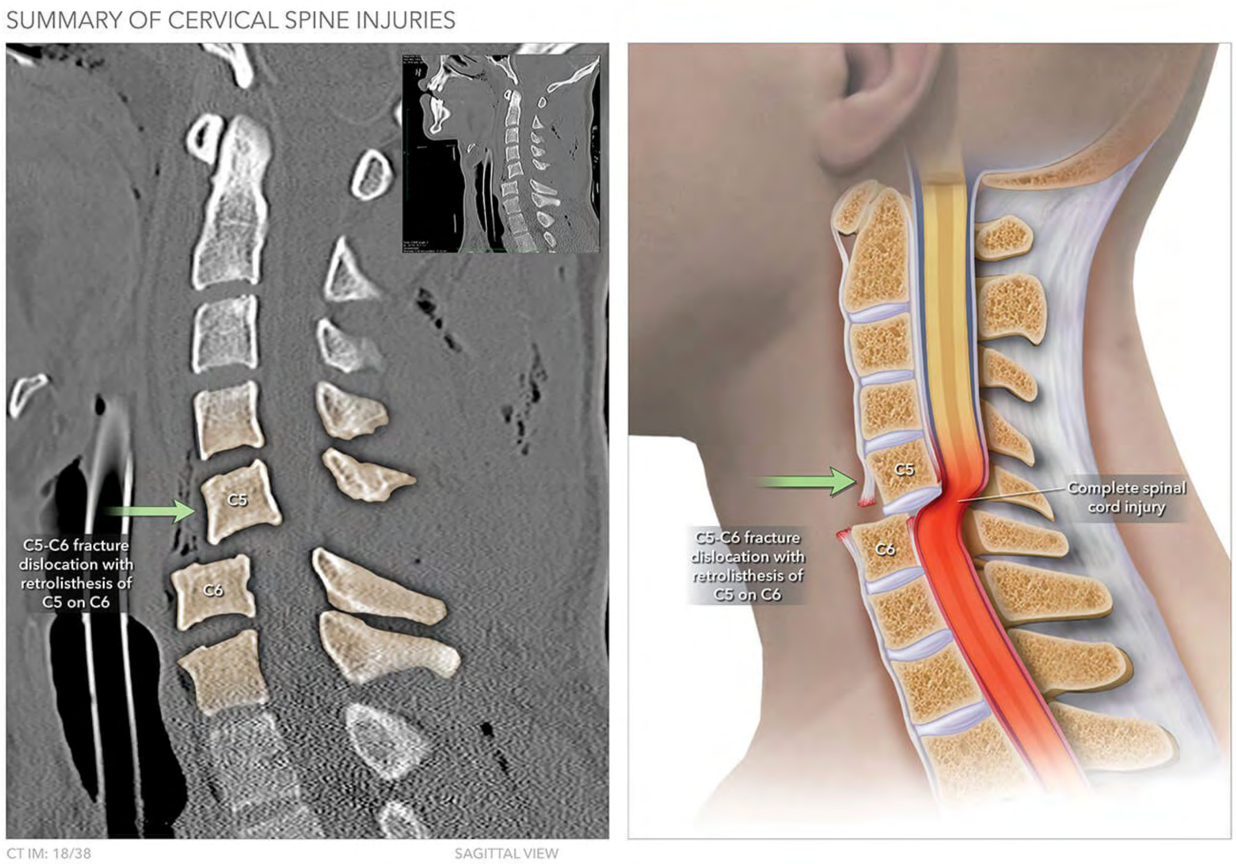




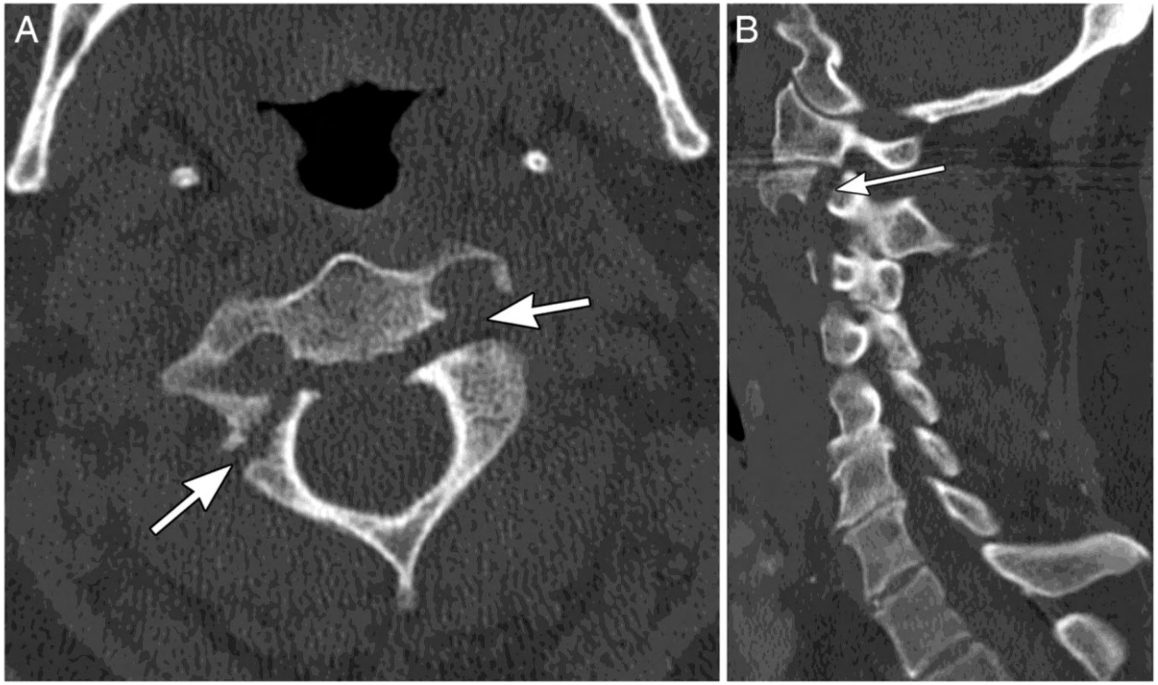
Posterior occipitoatlantal ligament
Transverse process of atlas
Vertebral artery
Spinous process of axis
Tectorial membrane
Occipital condyle
Anterior occipitoatlantal ligament
Vertebral artery
Apical ligament
Nuchal ligament
Anterior tubercle of atlas
Dens (odontoid process)
Transverse ligament
Posterior occipitoatlantal ligament
C1-2 facet joint
Posterior longitudinal ligament
Posterior tubercle of atlas
Anterior longitudinal ligament
Spinous process of axis
A
C2-3 facet joint
1
2
3
4
5
B
C

CV Junction AAD. #C2

Role of CT Scan

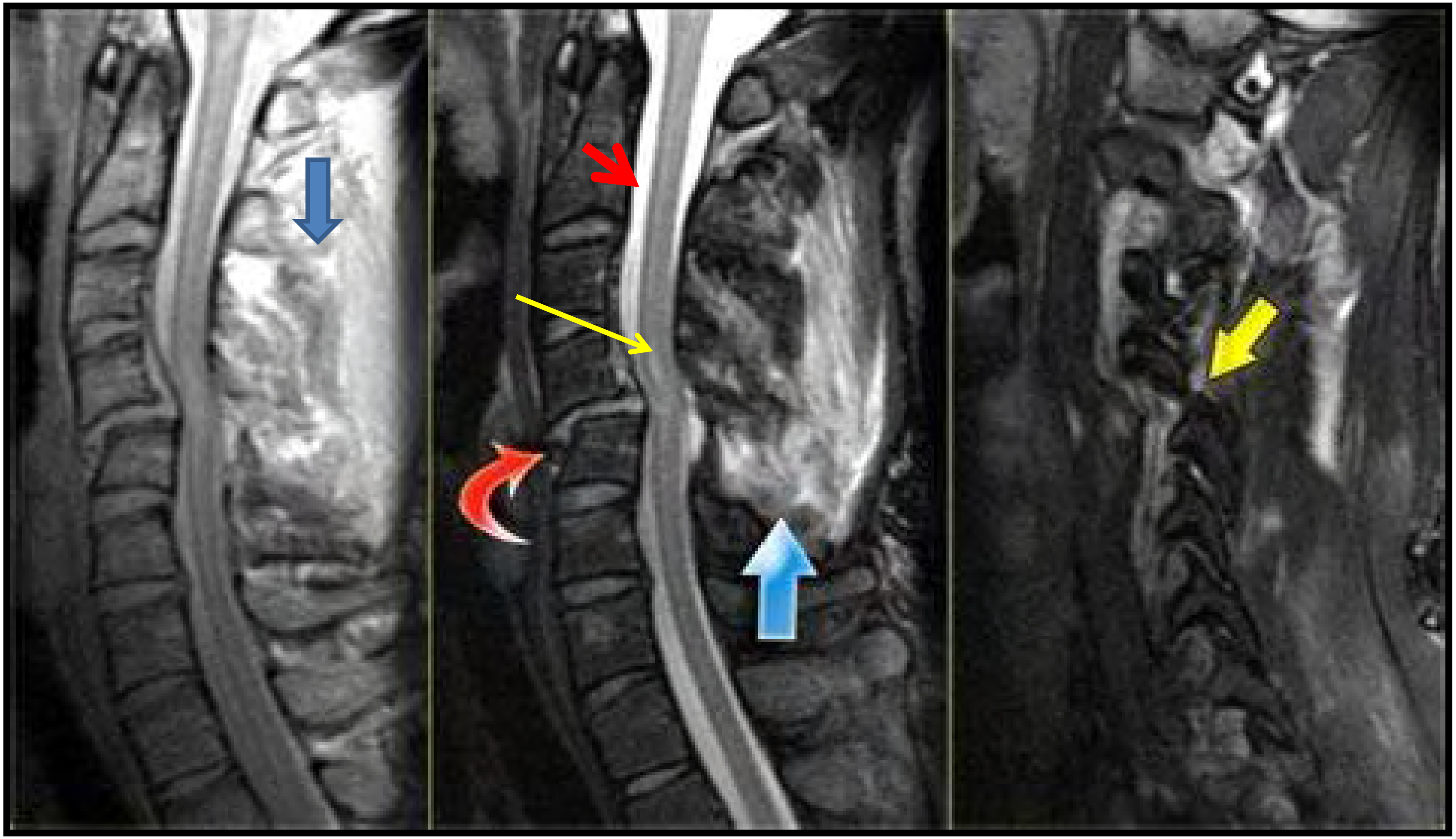


NCCT spine

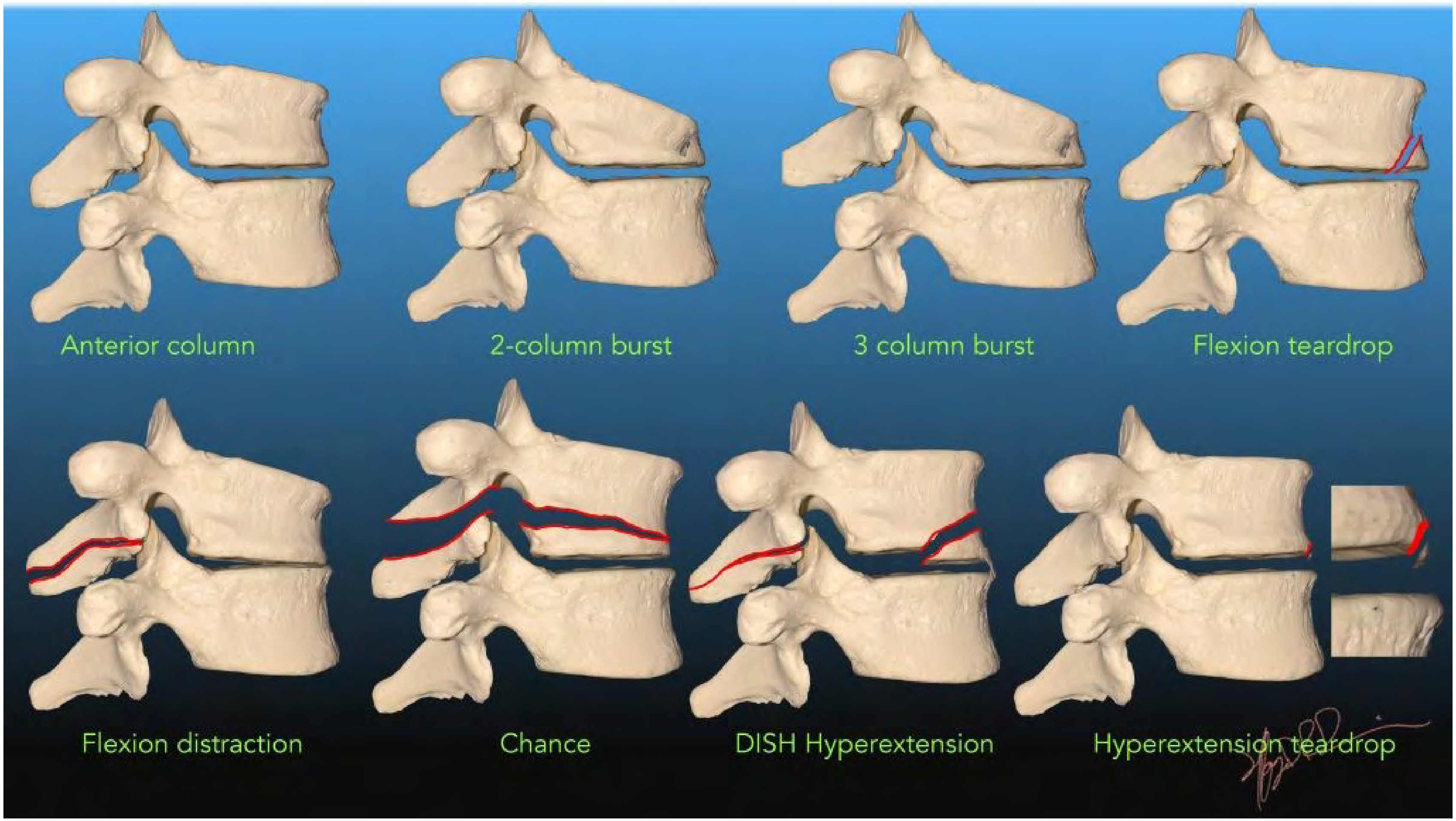


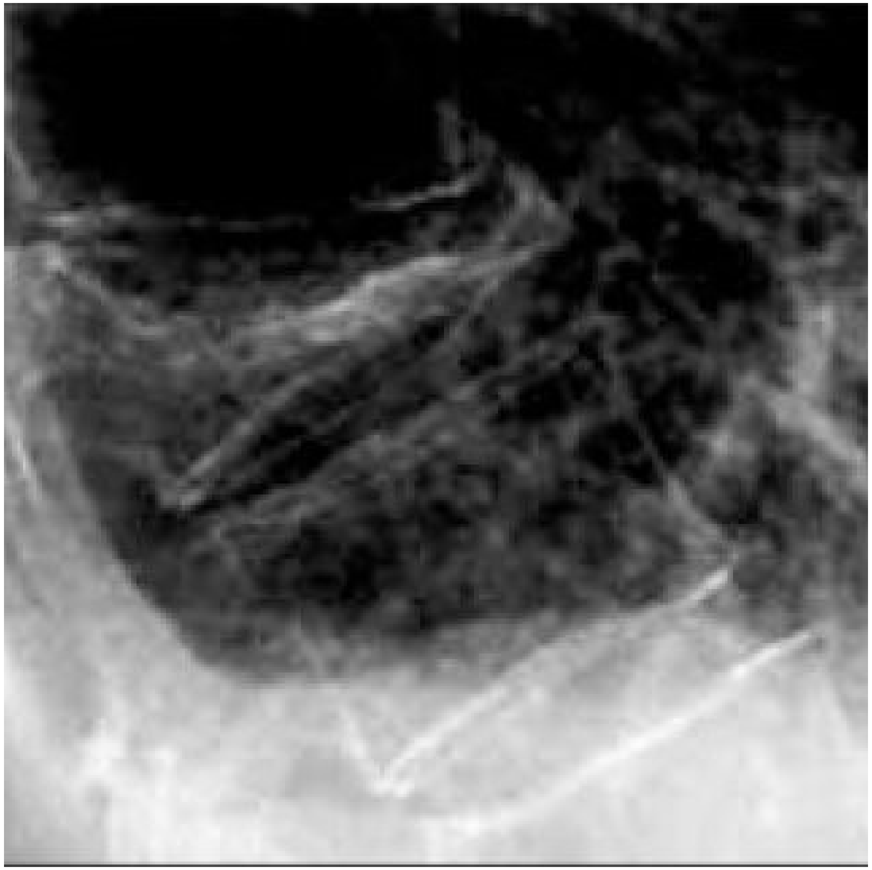
Role of MRI Spine


MRI Spine

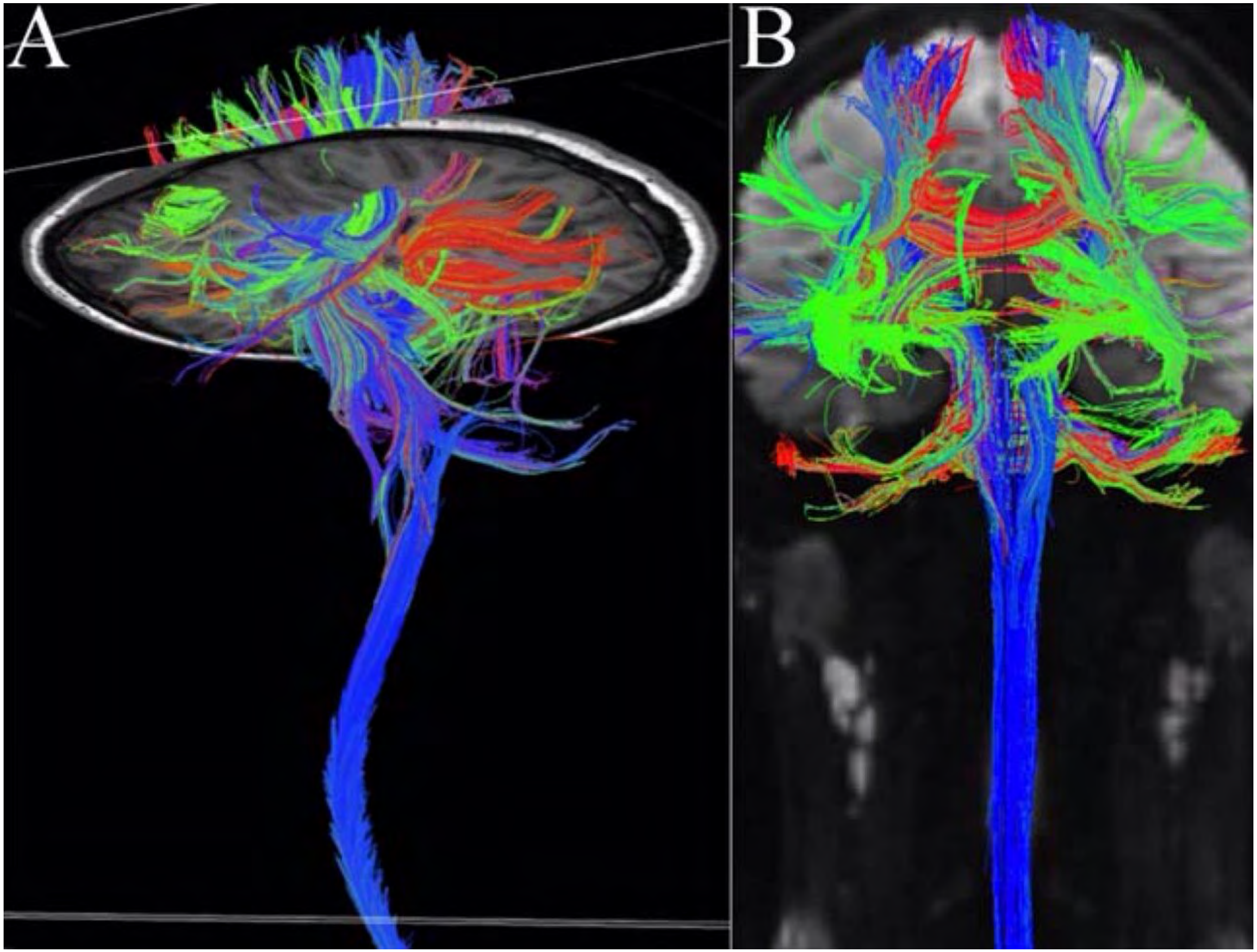


Complete Cord Transection

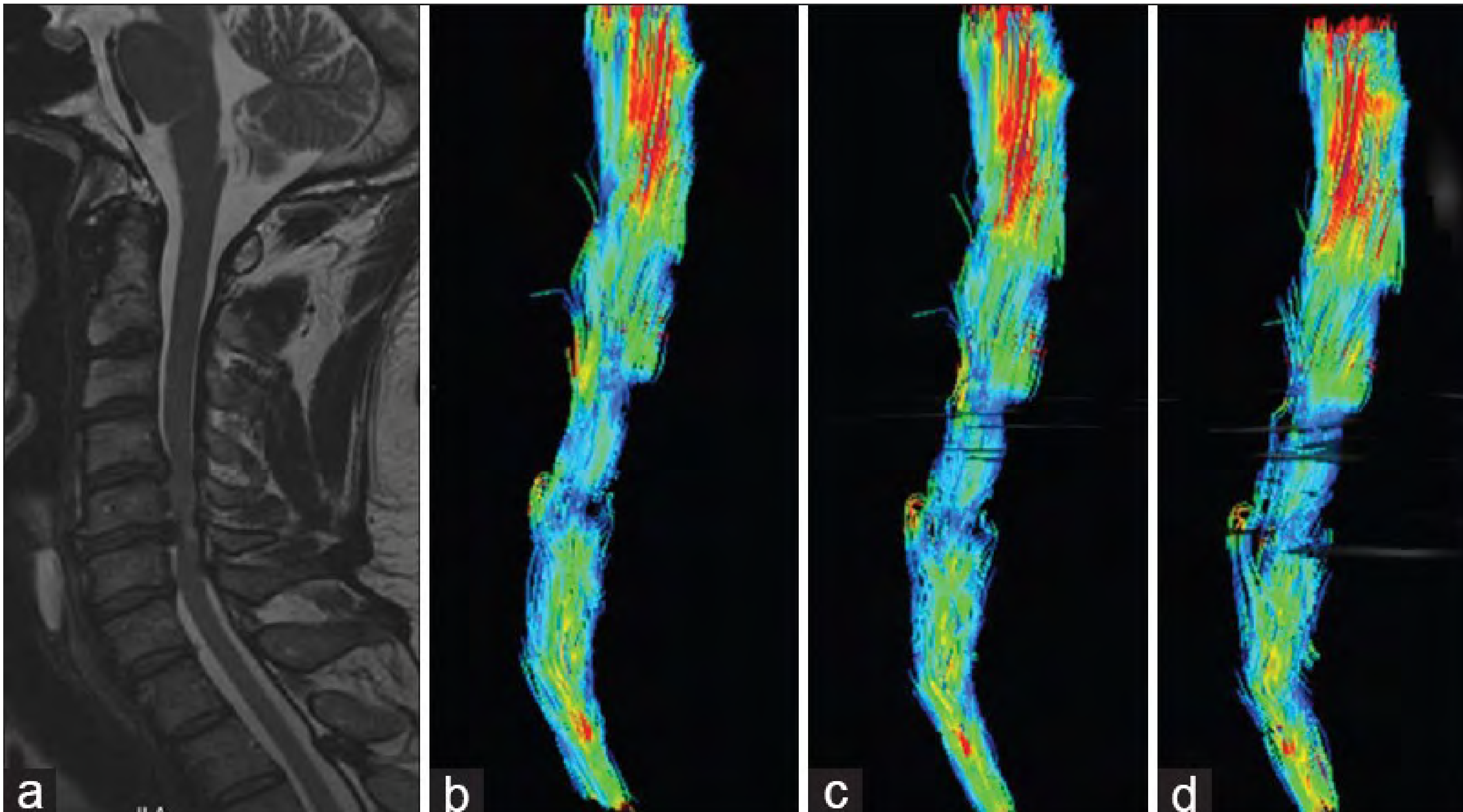

Anterior column
2-column burst
3 column burst
Flexion teardrop
Flexion distraction
Chance
DISH Hyperextension
Hyperextension teardrop



DTI- MR Tractography

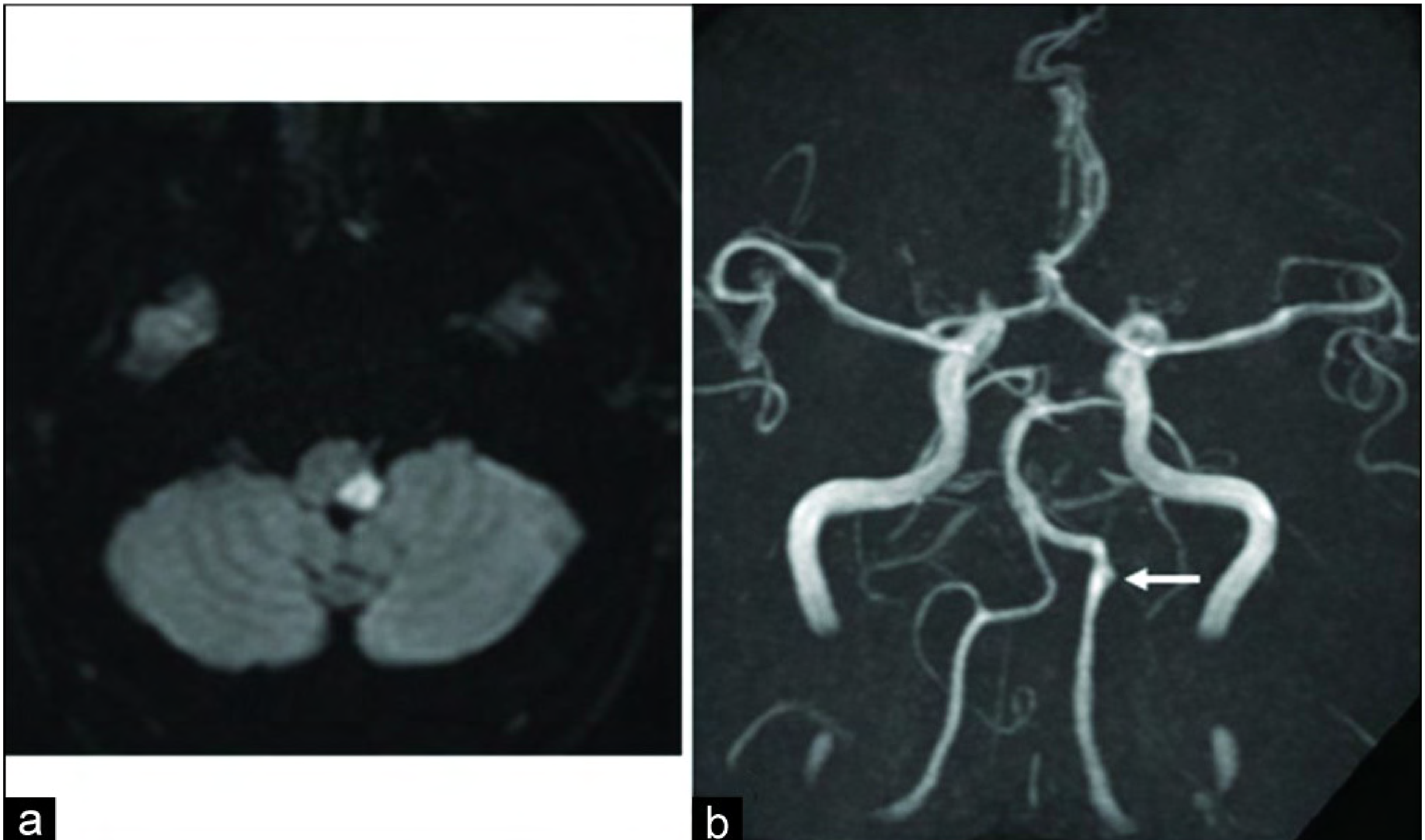


DTI

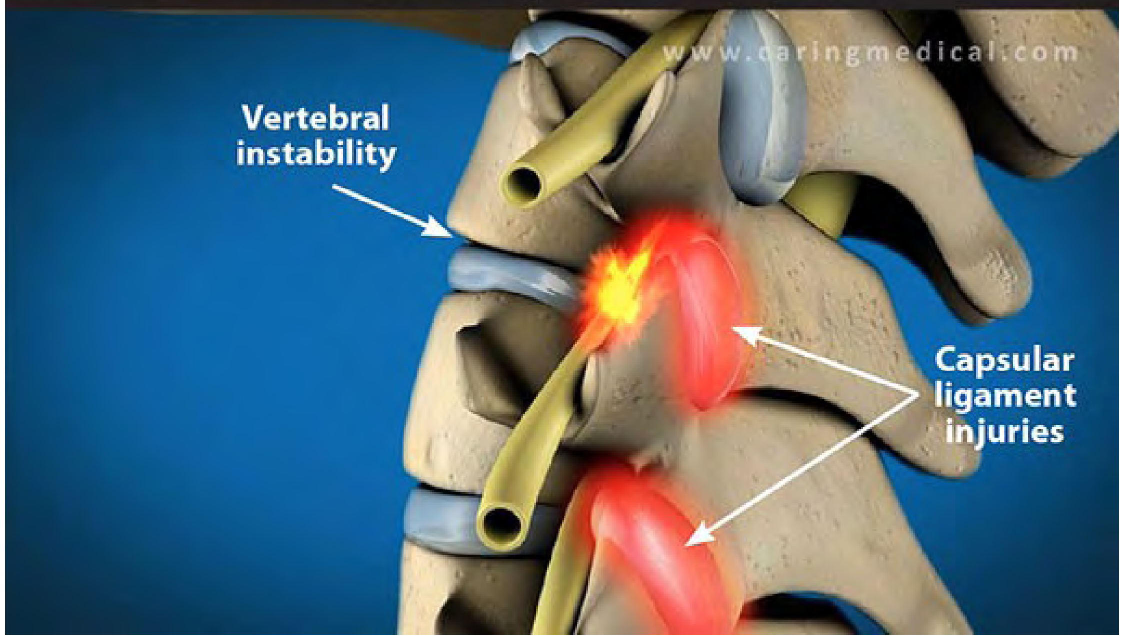


SCIWORA

Vertebral Artery Dissection



Capsular ligament injury causing cervical radiculopathy. When a person has a ligament injury in the neck, the vertebrae can sublux or move and then encroach on a nerve. This causes pain down the arm with certain neck movements. Prolotherapy resolves this type of cervical radiculopathy by stabilizing the vertebral movement by stimulating ligament repair.



Complications

- Syringomyelia
- Cord Atrophy
- Arachnoiditis
- Pachymeningitis

SCI : Concerns

- Infection Risk-Pnemonia
- Bed sores
- Venous Thromboembolism
- Bowel and Bladder Disorders
- Spasticity and decreased muscle tone
- Autonomic dysreflexia
- Sexual function
- Functional Outcomes and Role of Rehabilitation Services
- Depression

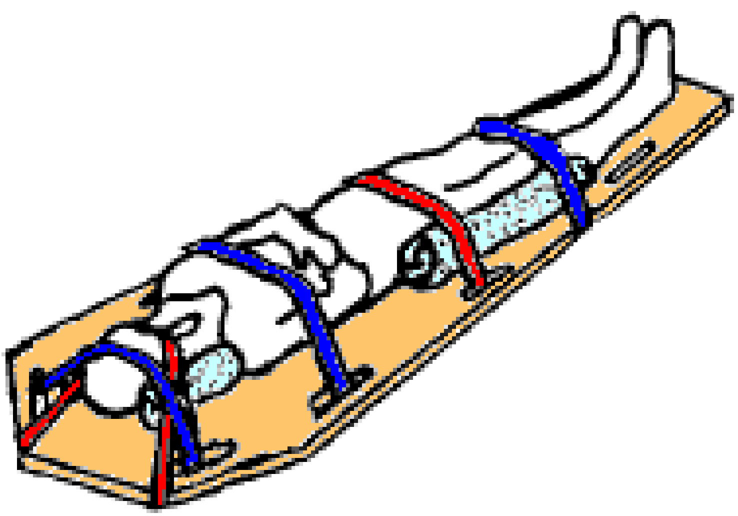
Treatment and options

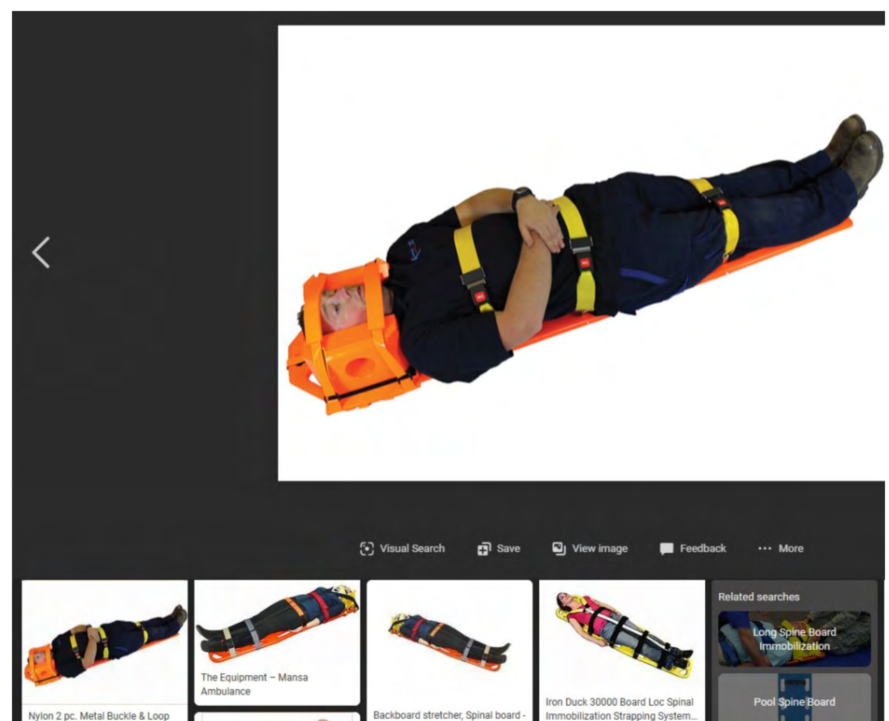
- **At the Scene of the Incident**

- Treatment for an SCI often begins at the scene of the injury.
- Immobilize the spine
- Use the carrying board to transport the patient to the hospital

Immobilization During Prehospital Transport

- Biomechanical studies recommend the combination of a rigid cervical collar with supportive blocks on a hard backboard with straps.





Initial Stabilization and Resuscitation

- Following SCI, early intubation and ventilation is indicated for patients with high cervical injuries (C1–5) causing impaired diaphragmatic breathing, respiratory depression, and CO_2 retention

- mandatory early intubation for any patient with complete lower cervical spine injury

- The 2005 Consortium for Spinal Cord Medicine's Clinical Practice Guidelines on Respiratory Management Following Spinal Cord Injury recommends the use of high tidal volume (VT; 20–25ml/kg ideal body weight).
- High VT is reportedly associated with earlier weaning off of mechanical ventilation and more rapid resolution of atelectasis in patients withSCI

- **In the Emergency Room**
- Maintaining the person's ability to breathe
- Immobilizing the neck to prevent further spinal cord damage
- Surgery.
- Traction.
- Methylprednisolone (Medrol). If this steroid medication is administered within 8 hours of injury, some patients experience improvement. It appears to work by reducing damage to nerve cells and decreasing inflammation near the site of injury.
- Experimental treatments.

Neuroprotective strategies

- Glucocorticoid methylprednisolone(Solumedrol
- Sodium channel blocker: riluzole,
- Nondrug therapy such as cerebrospinal fluid drainage,
- Blood pressure augmentation,
- Therapeutic hypothermia.

- Methylprednisolone can enhance neuron survival after injury by regulating the release of anti inflammatory cytokines and attenuating oxidative stress

- Riluzole reduces excitotoxicity influence to cells by preventing sodium influx and regulating glutamine release.
- Combined treatment of cerebrospinal fluid drainage and blood pressure augmentation can increase the blood supply and perfusion pressure in the injured area and prevent ischemic injury.
- Therapeutic hypothermia can reduce the basal metabolic rate of the central nervous system and improve the inflammatory response at the site of injury, while also reducing oxidative stress and excitotoxicity

Spinal Cord Perfusion and Vasopressor Support

- The joint guidelines of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons(CNS) for cervical spine injury management recommend *mean arterial pressure (MAP) > 85 mm Hg and avoid-ance of systolic blood pressure < 90 mm Hg for the first 5–7 days after SCI.*

- The Consortium for Spinal Cord Medicine recommends vasopressor choice by SCI level. Given the occurrence of bradyarrhythmias due to unopposed vagal tone in high cervical/thoracic injuries, agents with both α- and b-adrenergic activity (e.g., dopamine, norepinephrine)should be used to maintain MAP goals.

- In contrast, agents with pure a-adrenergic activity such as phenylephrine are adequate for lower thoracic injuries in which hypotension is more likely to result from vasodilation.

- Higher complication rates have been reported when vasopressors were used contrary to guidelines: e.g., use of dopamine for injuries below T-6

Medical management of SCI

- Methyl prednisolone (NASCIS1,2,3)
  - 30,G/kg bolus fb 5.4mg/kg over 23 hrs
  - Naloxone
  - Trilazad

  - Minocycline Tetracycline FDA Appd
  - Riluzole Na channel inhibitor FDA Appd
  - Mg PEG
  - Gacyclidine (NMDA)

- Rho-ROCK inhibitors
- anti-NOGO antibodies
- Hepatocyte growth factor
- GCSF
- Cell body therapy (mesenchymal, olfactory, bone marrow,Neuron precursor)
- Biomaterial Scaffold , Computer interphase, AI

Surgical Candidacy and Approach

- Thoracolumbar Injury Classification and Severity Score (TLICS)
- Subaxial Cervical Spine Injury Classification and Severity Score(SLIC)

A score < 4 suggests non operative management,
4 is borderline,
> 4 is an indication for operative management.

TABLE 1. Comparison of TLICS and SLIC systems

TLICS		SLIC	
Characteristic	Score	Characteristic	Score
Injury morphology		Injury morphology	
No abnormality	0	No abnormality	0
Compression	1	Compression	1
Burst component	2	Burst component	2
Translation/rotation	3	Translation/rotation	3
Distraction	4	Distraction	4
PLC integrity		DLC integrity	
Intact	0	Intact	0
Indeterminate	2	Indeterminate	1
Disrupted	3	Disrupted	2
Neurological status		Neurological status	
Intact	0	Intact	0
Nerve root injury	2	Nerve root injury	1
Complete cord injury	2	Complete cord injury	2
Incomplete cord injury	3	Incomplete cord injury	3
Cauda equina injury	3		

The TLICS and SLIC are used by summing the patient score in each category and using the final score to determine the next treatment step. For each scoring system, a score < 4 suggests nonoperative management, 4 is borderline, and > 4 is an indication for operative management.

Surgical Timing

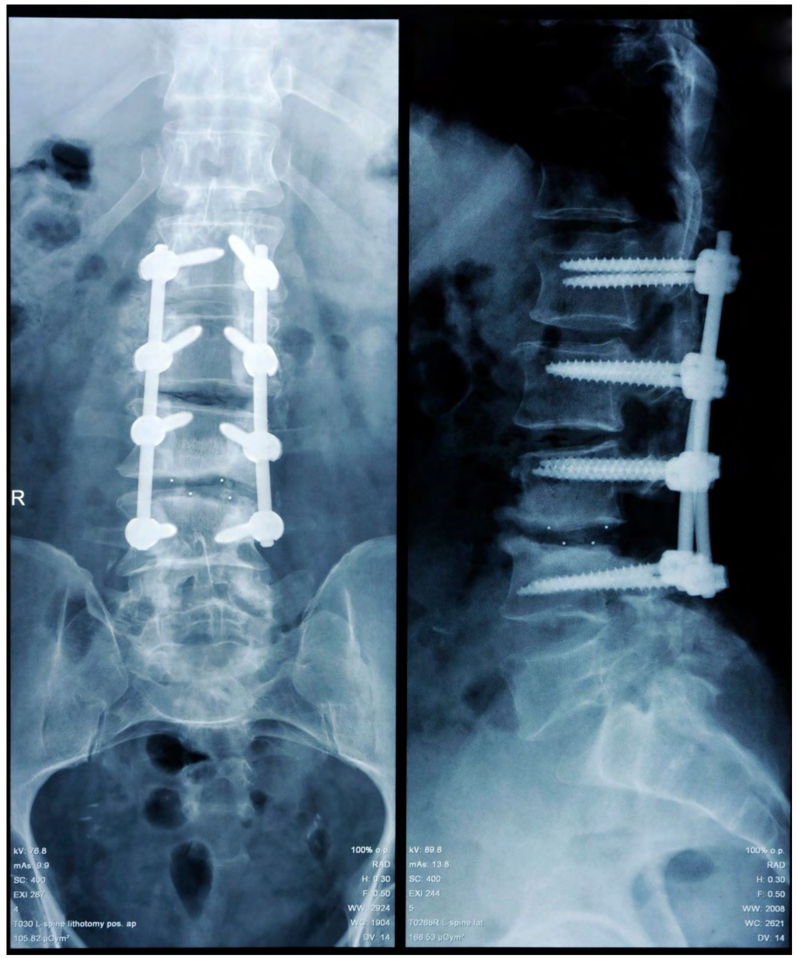
- prospective multicenter Surgical Timing in Acute Spinal Cord Injury Study trial conductedfrom 2002 to 2009 reports improved AIS grades amongpatients with acute cervical SCI who underwent early ver-sus late surgery.

- Early :within 24 hrs

AIMS OF SURGERY

Relieve compression
Stablisation of vertebral coloumn
Early mobilization of patient


Final POST OP lateral x-ray
After anteior C4 corpectomy
with cervical plate, and
posterior cervical stabilization
from C3 to C6.
L

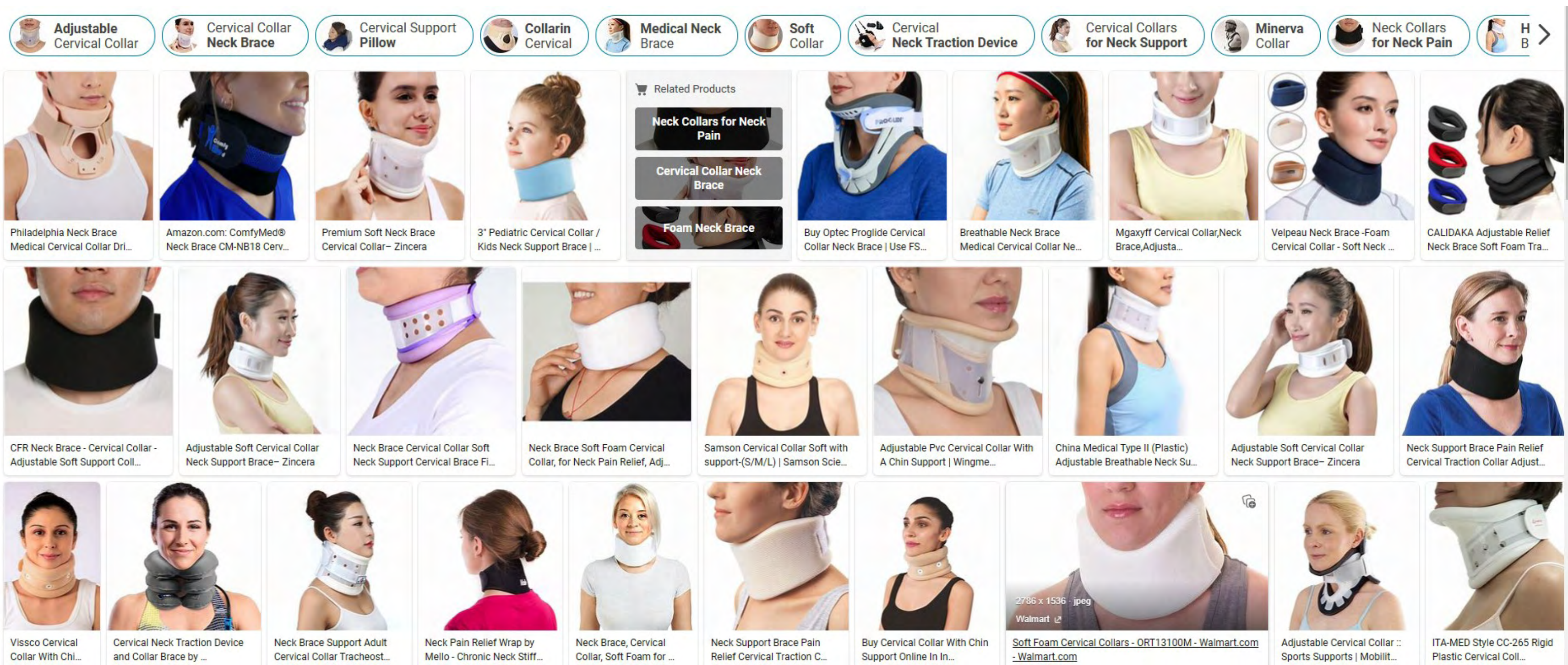

R
kV: 76.8
mAs: 9.9
SC: 400
EXI 287
4
T030 L-spine lithotomy pos. ap
105.82 µGym²
100% o.p.
RAD
H: 0.30
F: 0.50
WW: 2924
WC: 1904
DV: 14
kV: 89.8
mAs: 13.8
SC: 400
EXI 244
5
T026bR L-spine lat
166.53 µGym²
100% o.p.
RAD
H: 0.30
F: 0.50
WW: 2008
WC: 2621
DV: 14

Biomarkers for Early Diagnosis

- SCI include glial fibrillary acidic protein (GFAP),neurofilaments, cleaved tau, myelin basic protein, neuron-specific enolase, S100b, CD95 ligand.

- Predict severity of SCI
- Non specific
- May have limited role in prognosis of SCI

Rehabilitation


Adjustable Cervical Collar
Cervical Collar Neck Brace
Cervical Support Pillow
Collarin Cervical
Medical Neck Brace
Soft Collar
Cervical Neck Traction Device
Cervical Collars for Neck Support
Minerva Collar
Neck Collars for Neck Pain
Philadelphia Neck Brace Medical Cervical Collar Dri...
Amazon.com: ComfyMed® Neck Brace CM-NB18 Cerv...
Premium Soft Neck Brace Cervical Collar– Zincera
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CALIDAKA Adjustable Relief Neck Brace Soft Foam Tra...
CFR Neck Brace - Cervical Collar - Adjustable Soft Support Coll...
Adjustable Soft Cervical Collar Neck Support Brace– Zincera
Neck Brace Cervical Collar Soft Neck Support Cervical Brace Fi...
Neck Brace Soft Foam Cervical Collar, for Neck Pain Relief, Adj...
Samson Cervical Collar Soft with support-(S/M/L) | Samson Scie...
Adjustable Pvc Cervical Collar With A Chin Support | Wingme...
China Medical Type II (Plastic) Adjustable Breathable Neck Su...
Adjustable Soft Cervical Collar Neck Support Brace– Zincera
Neck Support Brace Pain Relief Cervical Traction Collar Adjust...
Vissco Cervical Collar With Chi...
Cervical Neck Traction Device and Collar Brace by ...
Neck Brace Support Adult Cervical Collar Tracheost...
Neck Pain Relief Wrap by Mello - Chronic Neck Stiff...
Neck Brace, Cervical Collar, Soft Foam for ...
Neck Support Brace Pain Relief Cervical Traction C...
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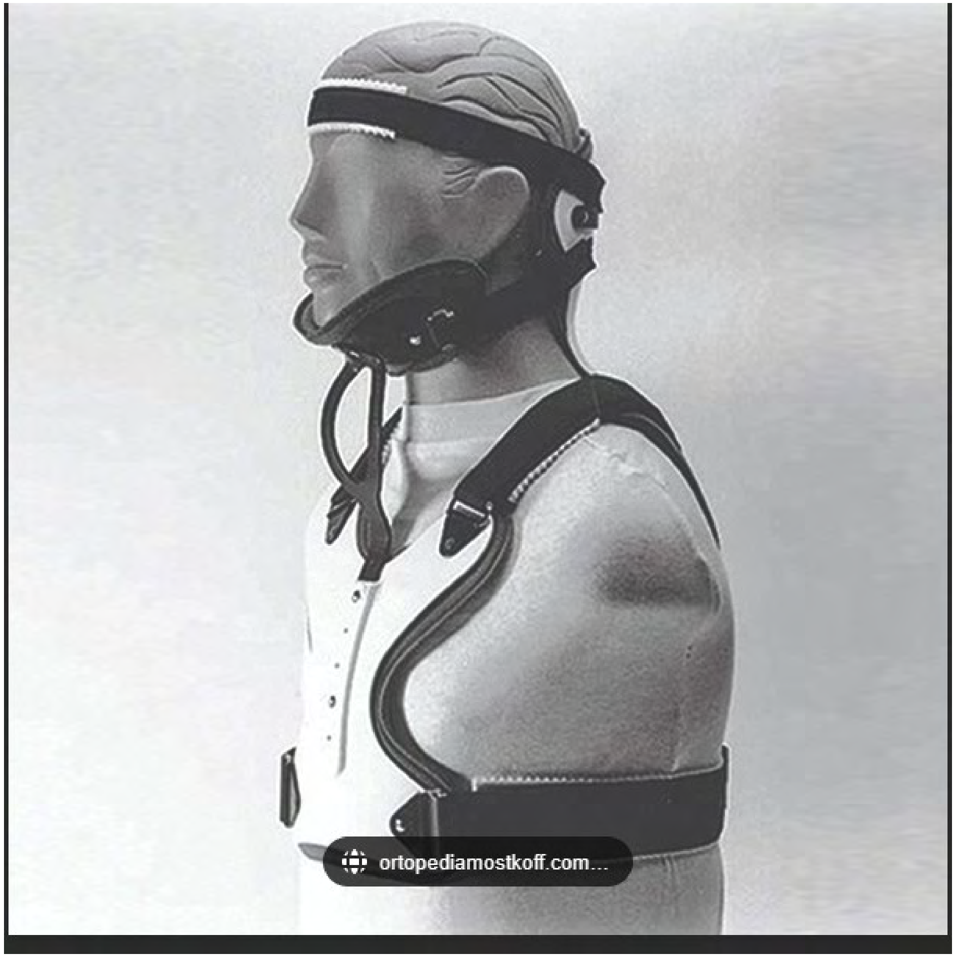
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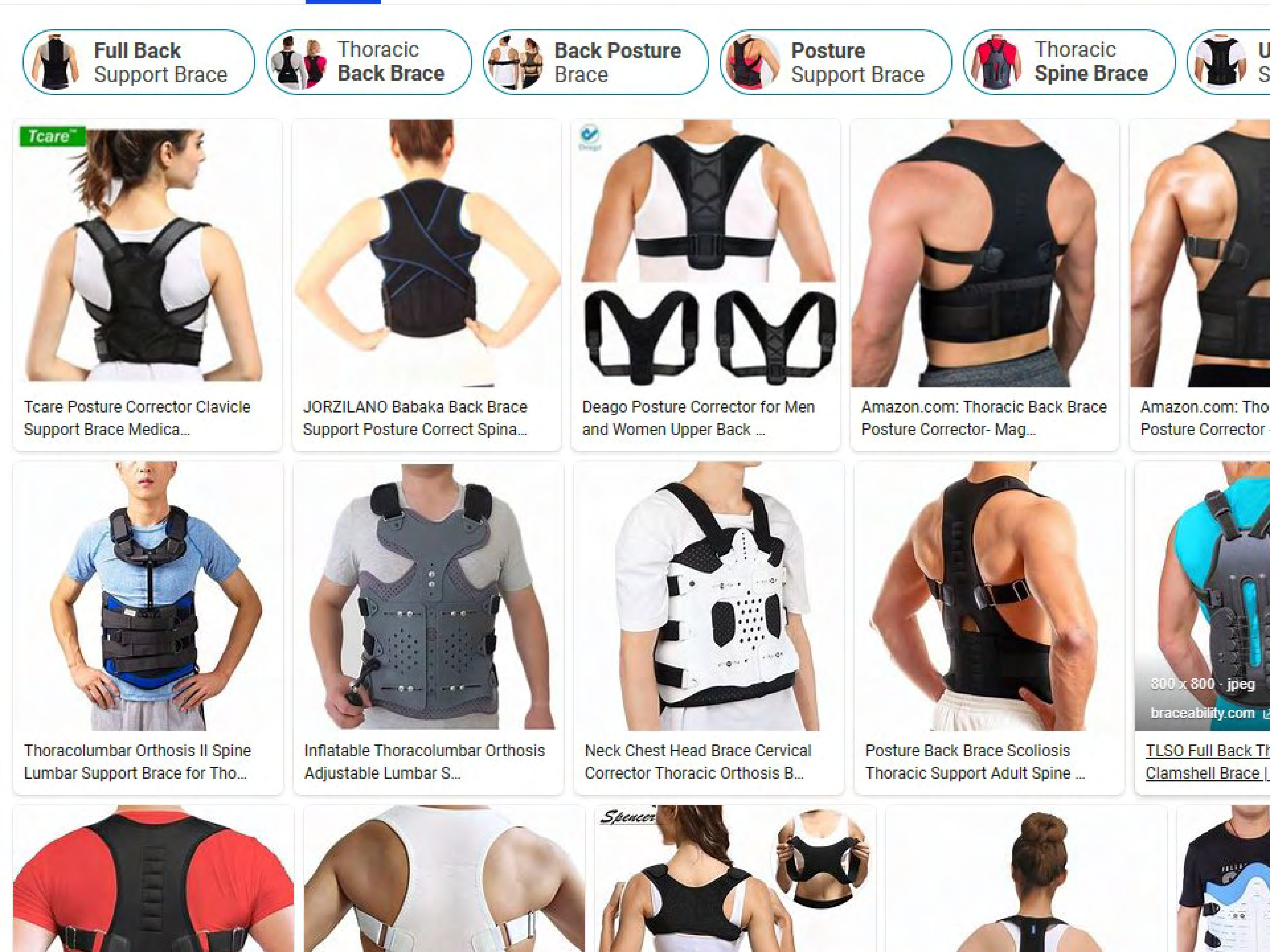

Full Back Support Brace
Thoracic Back Brace
Back Posture Brace
Posture Support Brace
Thoracic Spine Brace
Tcare
Tcare Posture Corrector Clavicle Support Brace Medica...
JORZILANO Babaka Back Brace Support Posture Correct Spina...
Deago Posture Corrector for Men and Women Upper Back ...
Amazon.com: Thoracic Back Brace Posture Corrector- Mag...
Amazon.com: Tho Posture Corrector
Thoracolumbar Orthosis II Spine Lumbar Support Brace for Tho...
Inflatable Thoracolumbar Orthosis Adjustable Lumbar S...
Neck Chest Head Brace Cervical Corrector Thoracic Orthosis B...
Posture Back Brace Scoliosis Thoracic Support Adult Spine ...
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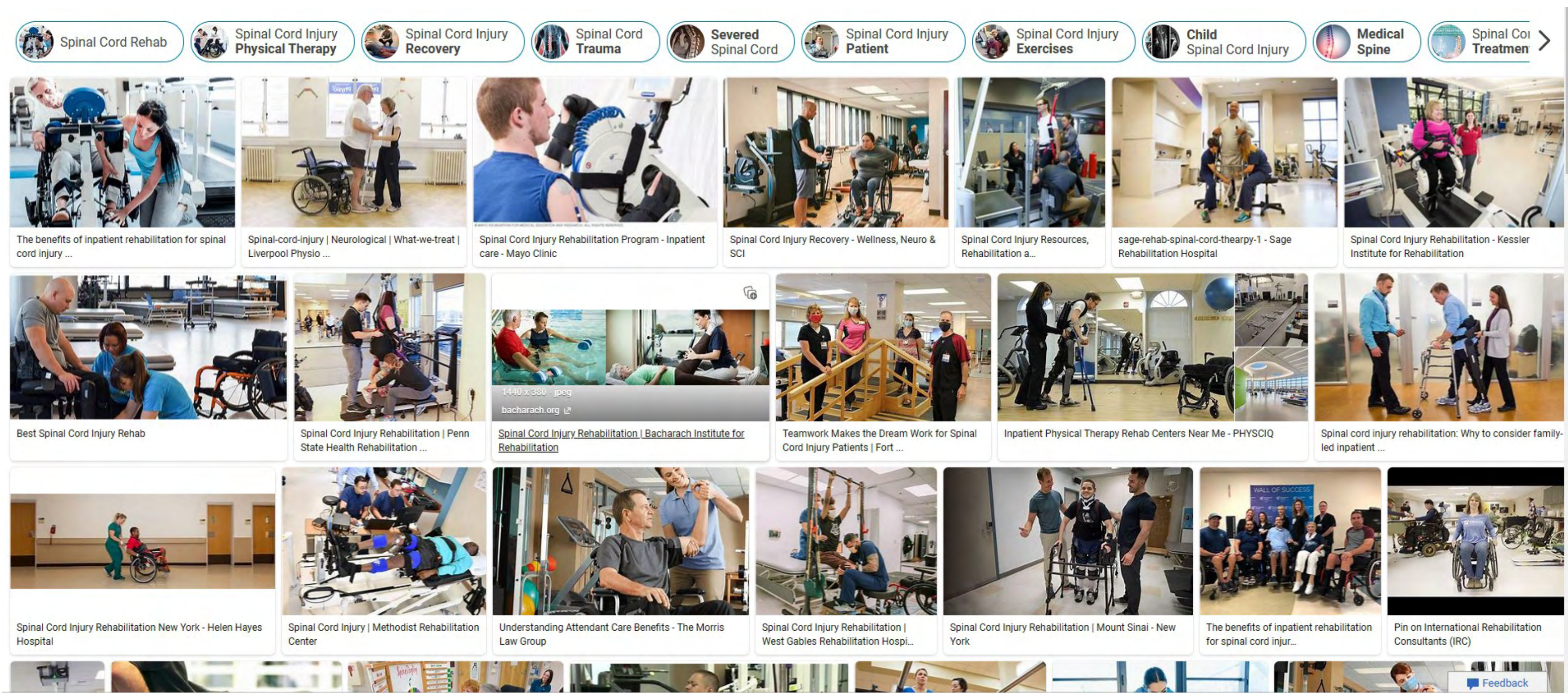
TLSO Full Back Th Clamshell Brace |
Spencer


Spinal Cord Rehab
Spinal Cord Injury Physical Therapy
Spinal Cord Injury Recovery
Spinal Cord Trauma
Severed Spinal Cord
Spinal Cord Injury Patient
Spinal Cord Injury Exercises
Child Spinal Cord Injury
Medical Spine
Spinal Cor Treatmen
The benefits of inpatient rehabilitation for spinal cord injury ...
Spinal-cord-injury | Neurological | What-we-treat | Liverpool Physio ...
Spinal Cord Injury Rehabilitation Program - Inpatient care - Mayo Clinic
Spinal Cord Injury Recovery - Wellness, Neuro & SCI
Spinal Cord Injury Resources, Rehabilitation a...
sage-rehab-spinal-cord-thearpy-1 - Sage Rehabilitation Hospital
Spinal Cord Injury Rehabilitation - Kessler Institute for Rehabilitation
Best Spinal Cord Injury Rehab
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The benefits of inpatient rehabilitation for spinal cord injur...
Pin on International Rehabilitation Consultants (IRC)
Feedback

Conclusions

- Spinal cord injury with polytrauma poses uniquely challenging considerations due to the increased risk of secondary insults to the spinal cord.
- Prehospital management should include appropriate spinal immobilization followed by timely transport to a trauma center.
- The initial assessment and management are focused on optimizing perfusion to the spinal cord.
- Poststabilization, diagnostic evaluation includes CT for bony fractures or overt cord pathology, and MRI in the patient with hemodynamic stability.
- Surgical stabilization depends on approach, timing,and perioperative management.
- Careful consideration ofinfection risk should be a priority for patients with trauma who have relative immunosuppression or compromise.
- Patients with polytrauma may experience longer rehabili-tation courses; however, long-term neurological recoveryis generally comparable to that for patients with isolatedSCI, after controlling for demographics.

- In the United States, about 12,000 people a year survive a spinal cord injury. The most commonly affected group are young adult males.[2] SCI has seen great improvements in its care since the middle of the 20th century. Research into potential treatments includes stem cell implantation, hypothermia, engineered materials for tissue support, epidural spinal stimulation, and wearable robotic exoskeletons.[3]

- . The *International Standards for Neurological Classification of Spinal Cord Injury* (ISNCSCI), published by the American Spinal Injury Association (ASIA), is widely used to document sensory and motor impairments following SCI.[12] It is based on neurological responses, touch and pinprick sensations tested in each dermatome, and strength of the muscles that control key motions on both sides of the body.[13] Muscle strength is scored on a scale of 0–5 according to the table on the right, and sensation is graded on a scale of 0–2: 0 is no sensation, 1 is altered or decreased sensation, and 2 is full sensation.[14] Each side of the body is graded independently.[14]

- **Complete and incomplete injuries**[edit]
- Level and completeness of injuries[17]CompleteIncompleteTetraplegia18.3%34.1%Paraplegia23.0%18.5%In a "complete" spinal injury, all functions below the injured area are lost, whether or not the spinal cord is severed.[9] An "incomplete" spinal cord injury involves preservation of motor or sensory function below the level of injury in the spinal cord.[18] To be classed as incomplete, there must be some preservation of sensation or motion in the areas innervated by S4 to S5,[19] e.g. voluntary external anal sphincter contraction.[18] The nerves in this area are connected to the very lowest region of the spinal cord, and retaining sensation and function in these parts of the body indicates that the spinal cord is only partially damaged. Incomplete injury by definition includes a phenomenon known as sacral sparing: some degree of sensation is preserved in the sacral dermatomes, even though sensation may be more impaired in other, higher dermatomes below the level of the lesion.[20] Sacral sparing has been attributed to the fact that the sacral spinal pathways are not as likely as the other spinal pathways to become compressed after injury due to the lamination of fibers within the spinal cord.[20]

- **Spinal cord injury without radiographic abnormality**[edit]
- Spinal cord injury without radiographic abnormality exists when SCI is present but there is no evidence of spinal column injury on radiographs.[21] Spinal column injury is trauma that causes fracture of the bone or instability of the ligaments in the spine; this can coexist with or cause injury to the spinal cord, but each injury can occur without the other.[22] Abnormalities might show up on magnetic resonance imaging (MRI), but the term was coined before MRI was in common use.[23]

- **Central cord syndrome**[edit]
- Incomplete lesions of the spinal cord: Central cord syndrome (top), Anterior cord syndrome (middle), and Brown-Séquard syndrome (bottom).
- Central cord syndrome, almost always resulting from damage to the cervical spinal cord, is characterized by weakness in the arms with relative sparing of the legs, and spared sensation in regions served by the sacral segments.[24] There is loss of sensation of pain, temperature, light touch, and pressure below the level of injury.[25] The spinal tracts that serve the arms are more affected due to their central location in the spinal cord, while the corticospinal fibers destined for the legs are spared due to their more external location.[25] The most common of the incomplete SCI syndromes, central cord syndrome usually results from neck hyperextension in older people with spinal stenosis. In younger people, it most commonly results from neck flexion.[26] The most common causes are falls and vehicle accidents; however other possible causes include spinal stenosis and impingement on the spinal cord by a tumor or intervertebral disc.[27]

- **Anterior spinal artery syndrome**[edit]
- Anterior spinal artery syndrome also known as *anterior spinal cord syndrome*, due to damage to the front portion of the spinal cord or reduction in the blood supply from the anterior spinal artery, can be caused by fractures or dislocations of vertebrae or herniated disks.[25] Below the level of injury, motor function, pain sensation, and temperature sensation are lost, while sense of touch and proprioception (sense of position in space) remain intact.[28][26] These differences are due to the relative locations of the spinal tracts responsible for each type of function.[25]

- **Brown-Séquard syndrome**[edit]
- Brown-Séquard syndrome occurs when the spinal cord is injured on one side much more than the other.[29] It is rare for the spinal cord to be truly hemisected (severed on one side), but partial lesions due to penetrating wounds (such as gunshot or knife wounds) or fractured vertebrae or tumors are common.[30] On the ipsilateral side of the injury (same side), the body loses motor function, proprioception, and senses of vibration and touch.[29] On the contralateral (opposite side) of the injury, there is a loss of pain and temperature sensations.[27][29]Spinothalamic tracts are in charge for pain and temperature sensation and because these tracts cross to the opposite side and above the spinal cord there is loss on the contralateral side.[31]

- **Posterior spinal artery syndrome**[edit]
- Posterior spinal artery syndrome (PSAS), in which just the dorsal columns of the spinal cord are affected, is usually seen in cases of chronic myelopathy but can also occur with infarction of the posterior spinal artery.[32] This rare syndrome causes the loss of proprioception and sense of vibration below the level of injury[26] while motor function and sensation of pain, temperature, and touch remain intact.[33] Usually posterior cord injuries result from insults like disease or vitamin deficiency rather than trauma.[34] Tabes dorsalis, due to injury to the posterior part of the spinal cord caused by syphilis, results in loss of touch and proprioceptive sensation.[35]

- **Conus medullaris and cauda equina syndromes**[edit]
- Conus medullaris syndrome is an injury to the end of the spinal cord the conus medullaris, located at about the T12–L2 vertebrae in adults.[29] This region contains the S4–S5 spinal segments, responsible for bowel, bladder, and some sexual functions, so these can be disrupted in this type of injury.[29] In addition, sensation and the Achilles reflex can be disrupted.[29] Causes include tumors, physical trauma, and ischemia.[36] Cauda equina syndrome may also be caused by central disc prolapse or slipped disc, infections such as epidural abscess, spinal haemorrhages, secondary to medical procedures and birth abnormalities.[37]
- Cauda equina syndrome (CES) results from a lesion below the level at which the spinal cord ends. Descending nerve roots continue as the cauda equina[34] at levels L2–S5 below the conus medullaris before exiting through intervertebral foraminae.[38] Thus it is not a true spinal cord syndrome since it is nerve roots that are damaged and not the cord itself; however, it is common for several of these nerves to be damaged at the same time due to their proximity.[36] CES can occur by itself or alongside conus medullaris syndrome.[38] It can cause low back pain, weakness or paralysis in the lower limbs, loss of sensation, bowel and bladder dysfunction, and loss of reflexes.[38] There may be bilateral sciatica with central disc prolapse and altered gait.[37] Unlike conus medullaris syndrome, symptoms often occur only on one side of the body.[36] The cause is often compression, e.g. by a ruptured intervertebral disk or tumor.[36] Since the nerves damaged in CES are actually peripheral nerves because they have already branched off from the spinal cord, the injury has better prognosis for recovery of function: the peripheral nervous system has a greater capacity for healing than the central nervous system.[38]

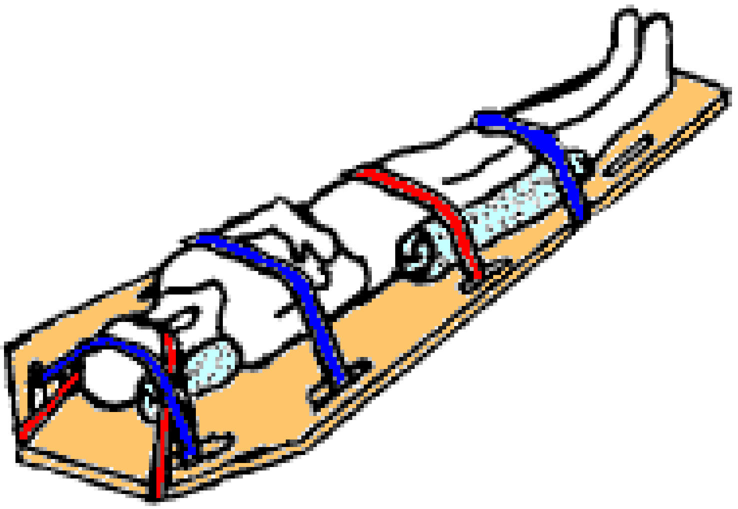
- History[edit]
- The ancient Egyptian Edwin Smith Papyrus is the earliest known description of SCI.[151]
- SCI has been known to be devastating for millennia; the ancient Egyptian Edwin Smith Papyrus from 2500 BC, the first known description of the injury, says it is "not to be treated".[151] Hindu texts dating back to 1800 BC also mention SCI and describe traction techniques to straighten the spine.[151] The Greek physician Hippocrates, born in the fifth century BC, described SCI in his Hippocratic Corpus and invented traction devices to straighten dislocated vertebrae.[152] But it was not until Aulus Cornelius Celsus, born 30 BC, noted that a cervical injury resulted in rapid death that the spinal cord itself was implicated in the condition.[151] In the second century AD the Greek physician Galen experimented on monkeys and reported that a horizontal cut through the spinal cord caused them to lose all sensation and motion below the level of the cut.[153] The seventh-century Greek physician Paul of Aegina described surgical techniques for treatment of broken vertebrae by removing bone fragments, as well as surgery to relieve pressure on the spine.[151] Little medical progress was made during the Middle Ages in Europe; it was not until the Renaissance that the spine and nerves were accurately depicted in human anatomy drawings by Leonardo da Vinci and Andreas Vesalius.[153]
- In 1762 a surgeon named Andre Louis removed a bullet from the lumbar spine of a patient, who regained motion in the legs.[153] In 1829 the surgeon Gilpin Smith performed a successful laminectomy that improved the patient's sensation.[154] However, the idea that SCI was untreatable remained predominant until the early 20th century.[155] In 1934, the mortality rate in the first two years after injury was over 80%, mostly due to infections of the urinary tract and pressure sores,[156] the latter of which were believed to be intrinsic to SCI rather than a result of continuous bedrest.[157] It was not until the second half of the century that breakthroughs in imaging, surgery, medical care, and rehabilitation medicine contributed to a substantial improvement in SCI care.[155] The relative incidence of incomplete compared to complete injuries has improved since the mid-20th century, due mainly to the emphasis on faster and better initial care and stabilization of spinal cord injury patients.[158] The creation of emergency medical services to professionally transport people to the hospital is given partial credit for an improvement in outcomes since the 1970s.[159] Improvements in care have been accompanied by increased life expectancy of people with SCI; survival times have improved by about 2000% since 1940.[160] In 2015/2016 23% of people in nine spinal injury centres in England had their discharge delayed because of disputes about who should pay for the equipment they needed.[161]

Research directions

- herapeutic research is focused on two main areas: neuroprotection and neuroregeneration.[76]
- Neuroprotective drugs target secondary injury effects including inflammation, damage by free radicals, excitotoxicity (neuronal damage by excessive glutamate signaling), and apoptosis (cell suicide).[76] Several potentially neuroprotective agents that target pathways like these are under investigation in human clinical trials.[76]

- Stem cell transplantation is an important avenue for SCI research: the goal is to replace lost spinal cord cells, allow reconnection in broken neural circuits by regrowing axons, and to create an environment in the tissues that is favorable to growth.[76] A key avenue of SCI research is research on stem cells, which can differentiate into other types of cells—including those lost after SCI.[76] Types of cells being researched for use in SCI include embryonic stem cells, neural stem cells, mesenchymal stem cells, olfactory ensheathing cells, Schwann cells, activated macrophages, and induced pluripotent stem cells.[162] Hundreds of stem cell studies have been done in humans, with promising but inconclusive results.[149] An ongoing Phase 2 trial in 2016 presented data[163] showing that after 90 days, 2 out of 4 subjects had already improved two motor levels and had thus already achieved its endpoint of 2/5 patients improving two levels within 6–12 months. Six-month data is expected in January 2017.

- Another type of approach is tissue engineering, using biomaterials to help scaffold and rebuild damaged tissues.[76] Biomaterials being investigated include natural substances such as collagen or agarose and synthetic ones like polymers and nitrocellulose.[76] They fall into two categories: hydrogels and nanofibers.[76] These materials can also be used as a vehicle for delivering gene therapy to tissues.[76]
- One avenue being explored to allow paralyzed people to walk and to aid in rehabilitation of those with some walking ability is the use of wearable powered robotic exoskeletons.[165] The devices, which have motorized joints, are put on over the legs and supply a source of power to move and walk.[165] Several such devices are already available for sale, but investigation is still underway as to how they can be made more useful.[165]
- Preliminary studies of epidural spinal cord stimulators for motor complete injuries have demonstrated some improvement[166] and in some cases to enable walking to some degree bypassing the injury[167][168]
- In 2014 Darek Fidyka underwent pioneering spinal surgery that used nerve grafts, from his ankle, to 'bridge the gap' in his severed spinal cord and olfactory ensheathing cells (OECs) to stimulate the spinal cord cells. The surgery was performed in Poland in collaboration with Prof. Geoff Raisman, chair of neural regeneration at University College London's Institute of Neurology, and his research team. The OECs were taken from the patient's olfactory bulbs in his brain and then grown in the lab, these cells were then injected above and below the impaired spinal tissue.[169]
- [170]



- **C 1-3 Spinal Cord Injury**
- **Functioning Muscles Include:**
  Infrahyoid – depresses hyoid, aiding tongue movement and swallowing
  Head and Neck Extensors
  Rectus capitus, anterior and lateral – neck flexion and side bending
  Sternocleidomastoid – neck extension, flexion, rotation, and side bending
  Longus Colli and Capitus – neck flexion
  Scalenes – neck side bending

- **C4 Spinal Cord Injury**
- **Additional Functioning Muscles:**
  Trapezius – shoulder elevation
  Upper Cervical paraspinals – neck flexion, extension, and lateral flexion
  Diaphragm – respiration

- **C5 Spinal Cord Injury**
- **Additional Functioning Muscles:**
  Rhomboids – scapular adduction
  Deltoids – shoulder abduction, flexion, extension, rotation
  Rotator Cuff (partial) –shoulder abduction
  Biceps – weak elbow flexion and forearm supination
  Brachialis, Brachioradialis – elbow flexion

- **C6 Spinal Cord Injury**
- **Additional Functioning Muscles:**
  Rotator Cuff (full innervation) – full rotation and abduction of shoulder
  Serratus Anterior – scapular abduction and upward rotation
  Clavicular Pectoralis Major – Shoulder horizontal adduction
  Biceps – full strength elbow flexion
  Extensor Carpi Radialis – wrist extension (Tenodesis can occur)

- **C7 Spinal Cord Injury**
- **Additional Functioning Muscles:**
  Latissimus Dorsi – shoulder internal rotation, adduction, depression
  Pectoralis Major (sternal head) – shoulder internal rotation, adduction, depression
  Triceps – elbow extension
  Pronator Teres – forearm pronation
  Flexor Carpi Radialis – wrist flexion
  Flexor Digitorum Superficialis – some finger flexion
  Extensor Digitorum – finger extension
  Extensor Pollicis – thumb extension

- **C8 Spinal Cord Injury**
- **Additional Functioning Muscles:**
  Flexor Digitorum Profundus and Superficialis – finger flexion
  Flexor Pollicis Longus and Brevis – thumb flexion
  Abductor Pollicis Longus – thumb abduction
  Opponens Pollicic – thumb opposition
  Adductor Pollicic – thumb adduction
  Partial Lumbricals – flexion at the MCP joints with extension of IP joint
  Flexor Carpi Ulnaris – wrist flexion
  Extensor Carpi Ulnaris – full wrist extension with adduction and abduction