REVIEW GROSS ANATOMY OF VERTEBRAE, SPINAL CORD AND SPINAL REFLEXES

1) Vertebrae
- Spinal Curvatures - normal and abnormal
- Vertebral Ligaments Herniation of Intervertebral Discs
- Regional Specializations/Landmarks of Vertebrae on CT

2) Spinal nerves
- Nerve Compression and Dermatome map
- Epidural Anesthesia and Lumbar Puncture (CSF)
- Spread of Disease to Vertebrae via Venous System

3) Spinal reflexes
- diagnosis of Upper and Lower Motor Neuron lesions
1) VERTEBRAE - NORMAL PRIMARY SPINAL CURVATURE

- Cervical (C1-C7)
- Thoracic (T1-T12)
- Lumbar (L1-L5)
- Sacral (S1-S5 fused)
- Coccygeal (Co1-3 to 5) variable, fused

Primary Curvature = Concave Anterior - fetal curvature

Primary Curvature retained in Adult Thorax, Sacrum

NOSE IS ANTERIOR

Primary Curvature retained in Adult Thorax, Sacrum
NORMAL SECONDARY CURVATURES - Develop in early childhood

Cervical curvature - concave posteriorly - helps support head

Lumbar curvature - concave posteriorly - develops with walking - helps support trunk, upper body
KYPHOSIS - 'hump' back - exaggerated curvature concave anteriorly in thorax in elderly - cause Osteoporosis, etc.

SCOLIOSIS - lateral curvature - can be due to 'presence of hemivertebra' - one half of a vertebra fails to develop

LORDOSIS - exaggerated posterior curvature - lumbar - cause obesity, etc.; (normal in pregnancy)
LIGAMENTS OF VERTEBRAE

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POSTERIOR LONGITUDINAL LIGAMENT - posterior to bodies (in canal)

LIGAMENTA FLAVA - connect laminae

ANTERIOR LONGITUDINAL LIGAMENT - anterior to bodies

SUPRASPINOUS LIG. - connect spines

INTERSPINOUS LIG. - connect spines

INTERVERTEBRAL DISC

BODY

VERTEBRAL CANAL

PEDICLE

LAMINA

SPINE

LATERAL VIEW

POSTERIOR VIEW

SAGITTAL VIEW
ANATOMY OF HERNIATION OF NUCLEUS PULPOSUS OF INTERVERTEBRAL DISCS

Herniation typically occurs in a Postero-Lateral Direction:
Postero-Lateral Direction: Post. Longitudinal Ligament is narrow; Ant. Longitudinal Ligament is broad; can produce nerve compression at intervertebral foramen
FEATURES OF CERVICAL VERTEBRA ON CT

Body is small, Vertebral canal is large

FORAMEN TRANSVERSARIUM
TRANSmits VERTEBRAL ARTERY

Damage to Cervical Vertebrae (ex. car accident) can damage Vertebral artery - neurological symptoms of brainstem lesion
FEATURES OF CERVICAL VERTEBRA ON CT

NOSE

C1 = ATLAS
C2 = AXIS

UPPER CERVICAL FRACTURE (C1 or C2) - QUADRIplegia; bilateral sensory loss in extremities

LOWER CERVICAL SPINAL NERVES FORM BRACHIAL PLEXUS

HERNIATION OF LOWER CERVICAL DISCS CAN PRODUCE SYMPTOMS IN UPPER EXTREMITY
LANDMARKS, FEATURES OF THORACIC VERTEBRA ON CT

ID: Ribs abut bodies (head of rib), transverse processes (tubercle of rib);

Landmark: Thoracic aorta anterolateral to bodies - extends down from arch of Aorta (located at Sternal Angle - T45 intervertebral disc)
FEATURES OF LUMBAR VERTEBRA ON CT

Landmarks:
- Erector spinae posterior;
- Psoas major anterior;
- IVC and Abdominal Aorta anterior to body.

ID: Large bodies; No surrounding bones.

Vertebral Canal

Body
2) GROSS ANATOMY OF SPINAL CORD AND SPINAL NERVES

VERTEBRAE

Cervical (C1-C7)
Thoracic (T1-T12)
Lumbar (L1-L5)
Sacral (S1-S5 fused)
Coccygeal (Co1-3(5)) fused

SPINAL NERVES

Cervical (C1-C8)
Thoracic (T1-T12)
Lumbar (L1-L5)
Sacral (S1-S5 fused)
Coccygeal (Co1)

CONVENTION FOR NAMING LEVELS:

C1 - C7: above vertebra
C8 - all others: below vertebra

Spinal nerves C1-C7 above vertebra
C8 and all others below vertebra
Clinical: Symptoms of compression of spinal root - Paresthesia (ex. tingling), pain, sensory loss, hyporeflexia, muscle weakness
Note: Overlap of dermatomes in region of trunk: sensory loss in trunk only with compression of two Thoracic spinal roots.
Questions: What is the level of a herniated disc that would produce numbness of Thumb? Little Finger? Big Toe?

Answers: Thumb, Disc C5-C6 above vertebra C6; Little Finger, Disc C7-T1 below vertebra C7; Big Toe, Disc L4-L5 below vertebra L4

Recall: C1 - C7: above vertebra; C8 - all others: below vertebra
Conus medullaris -
1. Newborn, Conus medullaris is located at vertebral level L3
2. Adult, Conus Medullaris is located at vertebral level L1

CONUS MEDULLARIS = INFERIOR END OF SPINAL CORD

LUMBAR PUNCTURE - BELOW LEVEL OF CONUS MEDULLARIS

SUPERIOR TO CONUS MEDULLARIS

CSF

INFERIOR TO CONUS MEDULLARIS

Level of Lumbar Puncture

Adult - between L3-L4 or L4-L5

Children - MUST be done at L4-L5

ROOTS OF CAUDA EQUINA

ROOTS OF CAUDA EQUINA
Spinal cord

Body of L2

Conus medullaris

Cauda equina

CSF in lumbar cistern

Conus medullaris

Spinal cord

FILUM TERMINALE - EXTENSION OF PIA MATER

CONUS MEDULLARIS

MRI

PROSECTION

CM

DRG

CAUDA EQUINA

CE

FT
SEQUENCE OF STRUCTURES PENETRATED IN EPIDURAL ANESTHESIA, LUMBAR PUNCTURE

5. Ligamentum Flavum (sudden yield, first 'pop') - now inside vertebral canal
6. Epidural space - STOP HERE FOR EPIDURAL ANESTHESIA
7. Dura mater (sudden yield, second 'pop')
8. Arachnoid - adherent to inner side of dura mater
9. Subarachnoid space (Lumbar cistern)- STOP HERE FOR LUMBAR PUNCTURE/SAMPLE CSF
ARTERIES AND VEINS OF SPINAL CORD

Radicular arteries

Posterior spinal arteries

Anterior spinal artery - branch of Vertebral A.

Anterior and Posterior spinal veins

Internal Vertebral Venous Plexus - in Epidural space

Intervertebral veins

DURA
Note: Disease processes can spread to spinal cord and vertebrae from other regions of the body by the vertebral venous plexus and intervertebral veins (e.g., carcinoma of the prostate in the pelvis can metastasize to the vertebral column).
3) SPINAL REFLEXES AND DIAGNOSIS OF UPPER AND LOWER MOTOR NEURON LESIONS

DEFINITION OF A REFLEX - SENSORY STIMULUS PRODUCES STEREOTYPED MOTOR RESPONSE

SENSORY STIMULUS \rightarrow \text{MOTOR RESPONSE}

FOR REFLEX TO OCCUR ALL ELEMENTS MUST BE FUNCTIONAL; PATHWAYS MUST BE INTACT
STRETCH (DEEP TENDON) REFLEX: MONOSYNAPTIC CONNECTION

SENSORY STIMULUS

Two methods:
1) Rapidly Stretch muscle (change muscle length)

2) TAP ON MUSCLE TENDON

MUSCLE LENGTH

Activate- Muscle spindle (Group Ia and II); monosynaptically excite Alpha (Lower) motor neuron to same muscle.

Muscle spindle - Sensory neurons (Ia, II) SIGNAL MUSCLE LENGTH

Sensory stimulus

MOTOR RESPONSE

Stretched muscle contracts rapidly

Excites Lower (Alpha) motor neuron in Ventral Horn

Note: Response large because also excite motor neurons to muscles with similar action and inhibit muscles with opposite action
**MUSCLE TONUS =**
resting tension in muscle

Tonus reflects firing of alpha motor neurons at rest

**TONUS -** Tested by physician slowly extending or flexing joints (stretching patient’s muscle)

Activity in muscle spindles at rest is important in determining Tonus because connection is monosynaptic

**REFLEXES CHANGED BY GAMMA MOTOR NEURONS - GET PATIENT TO RELAX BEFORE TESTING TONUS OR STRETCH REFLEX**

Gamma motor neurons innervate muscle cells in muscle spindles; Gamma motor neurons can heighten stretch reflexes (Gamma dynamic motor neurons specifically effect Ia sensory neurons)

**GAMMA MOTOR NEURONS -** innervate muscle cells in muscle spindles

**ALPHA MOTOR NEURONS -** innervate regular skeletal muscle cells
Upper motor neurons can modulate (change) reflexes by:

1)Changing excitability of alpha motor neurons
2) **Pre-synaptic Inhibition of la terminals**; reduces the amount of transmitter release at the synapse upon motor neuron.
LOWER MOTOR NEURON DISORDERS

1) Decreased stretch (tendon) reflexes - no activation of muscle
2) Decreased tonus - no tonic alpha motor neuron activity
3) Muscle atrophy - Fasciculations (twitches) precede atrophy - Alpha motor neurons fire spontaneously
4) No Babinski sign - no effect descending control

LOWER MOTOR NEURON - Flaccid Paralysis - muscle is effectively denervated (can affect single muscles)

Examples:
1) Compression of spinal nerve
2) Poliomyelitis - viral infections affecting motor neurons

UPPER MOTOR NEURONS - descending systems
UPPER MOTOR NEURON DISORDERS

1) Increased stretch (tendon) reflexes - No modulation, remove inhibition of reflex pathways
2) Increased tone - Remove inhibition of reflex pathways
3) No Fasciculations
4) Babinski sign - effect descending control of Flexor reflex
5) Clasped Knife Reflex - high forces activate Golgi tendon organs

Spastic Paralysis - affect groups of muscles
1) Increased stretch (tendon) reflexes - No modulation, remove inhibition of reflex pathways
2) Increased tone - Remove inhibition of reflex pathways
3) No Fasciculations
4) Babinski sign - effect descending control of Flexor reflex
5) Clasped Knife Reflex - high forces activate Golgi tendon organs

Example: Damage to Corticospinal (Corticobulbar) tracts - can occur at all levels from cortex to spinal cord (brainstem)
HYPERREFLEXIA: INCREASED STRETCH REFLEX ON ONE SIDE [used by permission of Paul D. Larsen, M.D., University of Nebraska Medical Center; http://library.med.utah.edu/neurologicexam]
CLASP-KNIFE PHENOMENON: FORCE ACTIVATES GOLGI TENDON ORGAN

GOLGI TENDON ORGANS SIGNAL MUSCLE FORCE - when force is high, activate Golgi Tendon Organ reflexes (Autogenic inhibition); inhibits alpha motor neurons, DECREASE FORCE

GOLGI TENDON ORGAN (GTO)

AUTOGENIC INHIBITION

GTO (lb)

Muscle tendon

Alpha motor neuron (inhibited)

SENSORY STIMULUS: FORCE ON MUSCLE TENDON

MOTOR RESPONSE: FORCE DECREASES

CLASP-KNIFE PHENOMENON

Physician applies, gradual forceful stretch of muscle: resistance to stretch builds until it suddenly gives way.

Hand of clinician
FLEXOR REFLEX

SENSORY STIMULUS - painful, irritating stimulus to skin

- Cutaneous afferent synapse onto Interneurons

- Interneurons make excitatory synapse onto Flexor motor neurons

- Note: Also excite extensor motor neurons in opposite leg (not fall down)

MOTOR RESPONSE

Cutaneous afferent

Interneurons

Flexor motor neuron

Step on nail

Lift leg

Extend opposite leg

KNEE JOINT
Babinski sign - seen after Upper Motor neuron lesion
-direction of movement changes from flexing toes to extending and fanning (abducting) toes
REFLEXES IN NEONATES: INFANT STEPPING PRODUCED BY PATTERN GENERATORS IN SPINAL CORD

REFLEXES IN NEONATES

PALMAR GRASP

MORO REFLEX - arm extend

STEPPING 'REFLEX' - actually eliciting a motor pattern

Infant Stepping - 'reflexes' are used to check motor function in neonates; holding infant with weight supported can elicit 'stepping' movements in legs

Stepping reflexes probably represents activation of Central Pattern Generator that produces walking movements

PATTERN GENERATOR - group of interneurons in CNS that are interconnected; produce activities in motor neurons and can generate rhythmic behaviors.
GOOD LUCK!