

OVERVIEW OF NERVOUS SYSTEM AND SPINAL CORD

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I. INTRODUCTION/DIVISIONS OF NERVOUS SYSTEM - The nervous system is the most complex system in the human body; required for human consciousness and behavior; irreversible cessation of function of nervous system is legal definition of death. Major divisions:

A. Central nervous system (**CNS**) - definition is precise; consists of **Brain** (contained in cranial cavity) and **Spinal Cord** (contained in vertebral canal).

B. Peripheral nervous system (**PNS**) = **everything else**; all of nervous system outside cranial cavity and vertebral canal; consists of 1) nerves (spinal nerves and cranial nerves) that carry signals to and from the CNS; 2) ganglia (collections of nerve cell bodies), 3) sense organs (eye, inner ear, etc.)

II. TERMINOLOGY OF NERVOUS SYSTEM

A. Terminology of axons in peripheral nerves - Afferent and Efferent

a. Afferent axons (also called sensory axons or just afferents) - axons of sensory neurons that conduct signals toward CNS (ex. sensory neurons signaling touch, taste, pain, etc.)

b. Efferent axons - axons of neurons that conduct signals away from CNS; most efferent axons are motor axons that cause contractions of muscles (ex. contract biceps muscle in arm); other efferents are more complicated (see Autonomic Nervous System lecture).

Reflexes - In some cases, sensory neurons (afferents) can produce rapid and automatic motor responses (exciting efferents); these reflex connections can be used clinically to evaluate nervous system function.

B. Terminology of types of nerves and convention about spinal levels - Spinal nerves and Cranial nerves are named for regions of nervous system they arise from/project to.

1. Cranial nerves - arise from/project to brain; there are 12 cranial nerves

2. Spinal nerves - arise from/project to spinal cord; there are 31 spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal).

Clinically Important Note: Cervical spinal nerves 1-7 (**C1-C7**) exit above corresponding vertebrae; Spinal nerve **C8** exits below vertebra **C7**; all other spinal nerves exit below corresponding vertebrae. (**RULE TO REMEMBER = C1-C7 ABOVE; ALL OTHERS BELOW**)

C. Major divisions of nervous system - terminology based upon function but can be confusing

1. Somatic Nervous system - considered voluntary, conscious part of nervous system

b. Somatic Afferents - sensory neurons that innervate skin, joints; provide precise conscious sensation of touch, pressure, pain etc to skin; also provide sense of body position.

- a. Somatic Efferents - motor neurons that control skeletal muscle; voluntary activities (ex. limb or eye movements, walking); conscious actions.
- 2. Autonomic Nervous system = Visceral nervous system - involuntary, unconscious part of nervous system
 - a. Visceral Afferents - sensory neurons that innervate internal organs, blood vessels; only provide imprecise localization of sensation and dull sense of pressure, pain, etc.
 - b. Visceral Efferents - control smooth and cardiac muscle, glands and internal organs; largely unconscious actions (autonomic means self-regulating or automatic)

Note: The Autonomic Nervous system will be covered in a number of lectures. It consists of Sympathetic and Parasympathetic divisions. The Sympathetic ganglia are located adjacent to the bodies of the vertebrae (called Paravertebral ganglia) inside the thorax (chest cavity).

III. SPINAL NERVES AND DERMATOMES - spinal cord is located within vertebral canal and is continuous with the brain at the medulla oblongata (inferior part of brain stem); dorsal and ventral rootlets that attach to the spinal cord along its length; dorsal rootlets unite to form dorsal root of spinal nerve; ventral rootlets unite to form ventral root. Spinal nerve forms when dorsal root joins ventral root (at intervertebral foramen); spinal nerves typically contain both sensory and motor axons.

A. Formation of a Spinal Nerve - spinal nerve forms from dorsal and ventral roots.

- 1. Dorsal root of spinal nerve - forms from series of dorsal rootlets; contains afferent (sensory) axons.
- 2. Dorsal root ganglion - cell bodies of all sensory neurons (somatic and visceral) are located at dorsal root ganglia; ganglia look like swellings attached to the dorsal root.
- 3. Ventral root of spinal nerve - forms from ventral rootlets; contains efferent (motor) axons.

B. Dermatome - is area of skin innervated by a single spinal nerve; very important clinically.

- 1. Structure - sensory axons from each spinal nerve end up innervating strips of skin on body called dermatomes; regions from different spinal nerves form a continuous series; in thorax dermatome map looks like stripes; more complex in extremities.
- 2. Overlap - there is some overlap between adjacent dermatomes; overlap is greater on trunk than on extremities
- 3. Clinical testing - damage to a single spinal nerve or single dorsal root can produce pain or anesthesia in its dermatome; physician can test for damage to a specific spinal nerve by lightly touch (pin prick) area of skin in dermatome.

Note: Because of overlap of dermatomes in region of trunk, damage to a single spinal nerve will not produce loss of sensation (anesthesia); loss of sensation on skin of trunk will occur if two or more adjacent dorsal roots or spinal nerves are damaged.

4. Specific Dermatomes Important in Extremities

- Lower Limb - L1 - skin over Inguinal ligament (anterior to hip joint);**
- L4 - Big Toe; S1 - Little Toe**
- Upper Limb - C6 - thumb; C7 - middle finger; C8 - little finger**

C. Dorsal and Ventral Rami (ramus = branch; pl. rami) of Spinal nerves - this is confusing; spinal nerves divide into Dorsal and Ventral Rami immediately after they leave the intervertebral foramen; both Dorsal and Ventral Rami contain sensory and motor axons; Dorsal Rami are much smaller than Ventral Rami.

1. **Dorsal Rami** (also called Dorsal Primary Rami) - contain sensory and **motor axons to region of back; sensory axons to skin of back and posterior neck**; motor axons go to Deep muscles of back and neck.

2. Ventral Rami (also called Ventral Primary Rami) - contain sensory and motor axons to other parts of body; sensory axons to skin of extremities (arm, leg) and anterior and lateral regions of trunk; motor axons to muscles of extremities and anterior and lateral regions of trunk; ventral primary rami also form plexuses (see below).

D. Plexus - (Latin for a braid) - formed from ventral rami of spinal nerves; ventral rami of spinal nerves interconnect in complex patterns; each plexus contains both sensory and motor axons; there are three major plexuses:

1. Cervical Plexus - innervates neck
2. Brachial Plexus - innervates upper extremity; forms from C5-T1 ventral rami
3. Lumbosacral Plexus - innervates lower extremity; forms from L1-S4 ventral rami.

Note: Each plexus gives rise to named nerves (ex. Sciatic Nerve from L45, S123).

IV. LOCATION OF SPINAL CORD IN VERTEBRAL CANAL - spinal column (vertebra) increases greatly in length in development; spinal cord only has small increase in size; in adult, vertebral canal is longer than spinal cord.

A. **Conus medullaris** - is **inferior (caudal) end** of spinal cord

1. In **newborn**, conus medullaris is located at vertebral level **L3**
2. In **adult**, conus medullaris is located at vertebral level **L1**.

B. **Cauda equina** (Latin for Horse's tail) - as vertebral column grows longer, lower dorsal and ventral rootlets also grow longer so they pass through correct intervertebral foramina; these rootlets extend inferior to conus medullaris at lower lumbar, sacral and coccygeal levels and are collectively called the Cauda Equina (located in vertebral canal, inferior to spinal cord).

V. MENINGES OF SPINAL CORD - meninges are layers of connective tissue that surround and protect nervous system; described as three layers.

A. Dura mater (Latin for tough mother) - tough outer layer that forms sac that completely surrounds spinal cord in vertebral canal; Dural sac surrounds also cauda equina below level L1 in adult (L3 in newborn); dural sac ends inferiorly at level S2.

1. Epidural space - dural sac is separated from inner side of vertebral canal by space (Epidural space) containing fat and loose connective tissue; also contains Internal Vertebral Venous plexus.

Clinical Note: Epidural Anesthesia - injection of anesthetic into epidural space can block conduction in spinal nerves; effect is by diffusion; this technique permits complete anesthesia (block pain and sensation) in limited areas of the body.

B. Arachnoid (Latin for spider like) - middle layer of meninges; attached to inner side of dura but has fine strands that extend to pia mater (like spider's web).

2. Subarachnoid space - found between arachnoid and pia; contains Cerebrospinal fluid.

C. Pia mater (Latin for tender mother) - thin layer that is adherent to surface of spinal cord; contains blood vessels supplying cord.

1. Denticulate Ligaments (denticulate, Latin for tooth like) - projections of pia on each side of cord that extend to inner side of Dura; there are 21 pairs of denticulate ligaments; denticulate ligaments stabilize spinal cord

Note: **Denticulate ligaments are used as landmarks** in neurosurgery; dorsal rootlets travel dorsal to denticulate ligaments; ventral rootlets are ventral to denticulate ligaments; can cut dorsal rootlets (dorsal rhizotomy) to relieve chronic pain using denticulate ligaments as guide.

2. Filum Terminale - pia extends as a thin strand below conus medullaris; strand traverses dural sac, pierces dural sac at S2 and continues inferiorly to attach at first coccygeal vertebra (Co1); the part of the filum terminale between S2 and Co1 is called the coccygeal ligament

VI. CEREBROSPINAL FLUID (CSF) AND SPINAL TAP - CSF is clear, acellular fluid contained in subarachnoid space; surrounds and protects spinal cord; produced within choroid plexuses (mostly in brain).

1. Changes in CSF can indicate disease processes - excessive CSF production (or decreased reabsorption) produces increased pressure (hydrocephalus); also blood cells in CSF can indicate infection or hemorrhage.

2. Lumbar Puncture (Spinal Tap) - CSF is sampled by inserting needle into Subarachnoid space; is performed with vertebral column flexed and patient sitting or lying on side (lateral decubitus position).

a. Level of Lumbar Puncture

- i. **Adult** - between **L3-L4** or **L4-L5** (spinal cord extends to L1)
- ii. **Children** - done at **L4-L5** (spinal cord at birth extends to L3)

b. Structures needle passes through in lumbar puncture to in midline to enter Subarachnoid space - superficial to deep

- i. Skin
- ii. Superficial Fascia
- iii. Supraspinous ligament
- iv. Interspinous ligament
- v. **Ligamentum flavum (sudden yield, first 'pop')**

- vi. Epidural space (connective tissue and fat) - **stop here for Epidural anesthesia**
- vii. **Dura mater (sudden yield, second 'pop')**
- viii. Arachnoid - adherent to inner side of dura

You are now in space for sampling Cerebrospinal fluid

VII. SUMMARY OF DEFINITIONS AND FACTS FROM OVERVIEW OF NERVOUS SYSTEM LECTURE

TERMINOLOGY

Central nervous system (CNS) = brain and spinal cord

Peripheral nervous system (PNS) = all nerves, ganglia, sense organs outside CNS

Cranial nerves = nerves that arise from brain (there are 12 cranial nerves)

Spinal nerves = nerves that arise from spinal cord (there are 31 spinal nerves)

Afferent axons = axons of sensory neurons (conduct toward CNS)

Efferent axons = axons of motor neurons, neurons of autonomic nervous system; (conduct away from CNS)

Somatic = voluntary

Somatic efferents - axons innervate skeletal muscle;

Somatic afferents - sensory neurons innervate skin, joints muscles (also oral cavity and nasal cavity); sensory perception is precise

Visceral = involuntary

Visceral efferents (= AUTONOMICS) - innervate smooth muscle, glands, gut, blood vessels

Visceral afferents - sensory neurons innervate internal organs; sensory perception is imprecise

Reflex - a stereotyped motor (muscle) response to a specific sensory signal.

Flexor Reflex - sensory - stepping on nail; motor - lift leg

Stretch (Deep Tendon Reflex - sensory - stretch muscle (tap on tendon); motor - muscle contracts.

REVIEW FACTS, LEVELS

Levels of spinal nerves = C1-C7 above vertebra, C8 and all other below vertebra)

Dermatome = area of skin innervated by single spinal nerve or cranial nerve

Dorsal root ganglion - contains cell bodies of sensory neurons (no synapses)

Dorsal root of spinal nerve - contains afferent (sensory) axons

Ventral root of spinal nerve - contains efferent axons

Dorsal ramus of spinal nerve - sensory and motor axons going to skin and muscles of the back

Ventral ramus of spinal nerve - sensory and motor axons going to skin and muscles of rest of body

Denticulate ligaments - extension of pia mater, attach to dura

Dermatomes of upper extremity - C6 thumb, C8 little finger

Spinal cord ends inferiorly - L1 in adult, L3 in children

Lumbar puncture - do at L3-4, L4-5 in adults; L4-5 in children

Lumbar puncture structures passed through - SFSIFpopEDpopA (see lecture)

Dural sac ends - S2 (adult)

Filum terminale attaches inferiorly - Co1 (first Coccygeal vertebra)