Chapter 12b

Spinal Cord

Overview

- Spinal cord gross anatomy
- Spinal meninges
- Sectional anatomy
- Sensory pathways
- Motor pathways
- Spinal cord pathologies
The Adult Spinal Cord

- About 18 inches (45 cm) long
- 1/2 inch (14 mm) wide
- CNS tissue ends between vertebrae L₁ and L₂
  - At birth, cord and vertebrae are about the same size but cord stops elongating at around age 4
- 31 segments (31 pairs of spinal nerves)
- Each pair of nerves exits the vertebral column at the level it initially lined up with at birth

Gross Anatomy of the Spinal Cord
Distal End

- **Conus medullaris:**
  - thin, conical end of the spinal cord
- **Cauda equina:**
  - nerve roots extending below conus medullaris
- **Filum terminale:**
  - thin thread of fibrous tissue at end of conus medullaris
  - attaches to coccygeal ligament

Size of cord segments

- The more superior, the more white matter. Why do you think this is?
- Grey matter larger in cervical and lumbar regions. Why is this?
31 Spinal Cord Segments

- C8, T12, L5, S5, Co1
- Based on vertebrae where spinal nerves originate
- Positions of spinal segment and vertebrae change with age
- Spinal nerves originally line up with their exit point from the cord.
- Even after the vertebral column grows much longer, each pair of spinal nerves still exits at its original location, now several segments away

Roots

- 2 branches of spinal nerves:
  - ventral root:
    - contains axons of motor neurons
  - dorsal root:
    - contains axons of sensory neurons
- Dorsal root ganglia:
  - contain cell bodies of sensory neurons
  - Pseudounipolar neurons - weird
Spinal Meninges

- Specialized membranes isolate spinal cord from surroundings
- **Spinal meninges:**
  - protect spinal cord
  - carry blood supply
  - continuous with cranial meninges
Spinal Meninges

Dura mater: outer layer
Arachnoid mater: middle layer
Pia mater: inner layer

The Spinal Dura Mater

- Are tough and fibrous
- Cranially:
  - fuses with periosteum of occipital bone
  - continuous with cranial dura mater
- Caudally:
  - tapers to dense cord of collagen fibers
  - joins filum terminale in coccygeal ligament (for longitudinal stability)
The **Epidural Space**

- Between spinal dura mater and walls of vertebral canal (above the dura)
- No such space in the brain
- Contains loose connective and adipose tissue
- Anesthetic injection site

**Inter-Layer Spaces – just like in the brain**

- **Subdural space:**
  - between arachnoid mater and dura mater
- **Subarachnoid space:**
  - between arachnoid mater and pia mater
  - filled with *cerebrospinal fluid (CSF)*
- **Spinal Tap** withdraws CSF from inferior lumbar region (below conus medularis) for diagnostic purposes.
- Where do they get the CSF?
Lumbar Tap

Spinal Cord – general features

• Spinal cord has a narrow, fluid filled central canal
• Central canal is surrounded by butterfly or H-shaped gray matter containing sensory and motor nuclei (soma), unmyelinated processes, and neuroglia
• White matter is on the outside of the gray matter (opposite of the brain) and contains myelinated and unmyelinated fibers
Sectional Anatomy of Spinal Cord

- Four zones are evident within the gray matter – somatic sensory (SS), visceral sensory (VS), visceral motor (VM), and somatic motor (SM)

Rule

- Sensory roots and sensory ganglia are dorsal
- Motor roots are motor nuclei are ventral
Gray Matter Organization

- **Dorsal (Posterior) horns:**
  - contain somatic and visceral **sensory** nuclei
- **Ventral (Anterior) horns:**
  - contain somatic **motor** nuclei
- **Lateral horns:**
  - are in thoracic and lumbar segments only
  - contain visceral motor nuclei
Control and Location

• Location of cells (nuclei) within the gray matter determines which body part it controls. For example:
  – Neurons in the ventral horn of the lumbar cord control the legs and other inferior body structures
  – Neurons in the dorsal horn of the cervical cord are sensory for the neck and arms

Dermatomes

• Bilateral region of skin
• Each is monitored by specific pair of spinal nerves
Organization of White Matter

- 3 columns on each side of spinal cord:
  - posterior white columns
  - anterior white columns
  - lateral white columns

Tracts

- Tracts (or fasciculi):
  - bundles of axons in the white columns
  - relay certain type of information in same direction
- Ascending tracts:
  - carry information to brain
- Descending tracts:
  - carry motor commands to spinal cord
Summary

- Gray matter is central
- Thick layer of white matter covers it:
  - consists of ascending and descending axons
  - organized in columns
  - containing axon bundles with specific functions
- Spinal cord is so highly organized, it is possible to predict results of injuries to specific areas

Somatic Sensory Pathways

- Carry sensory information from the skin and musculature of the body wall, head, neck, and limbs to the spinal cord and up to the brain.
- Pathways consist of:
  - 1: receptor cell: to spinal cord (or brain stem)
  - 2: spinal cord cell: to thalamus
  - 3: thalamus cell: to primary sensory cortex
- Some cross over in the cord or medulla
First-Order Neuron

- Sensory neuron delivers sensations to the CNS
- Cell body of a first-order general sensory neuron is located in dorsal root ganglion or cranial nerve ganglion
- Distal end of these DRG cells have endings that monitor specific conditions in the body or external environment (e.g. Merkel discs or free nerve endings in the skin)

Second-Order Neuron

- Axon of the sensory neuron synapses on an interneuron in the CNS
- May be located in the spinal cord or brain stem
- If the sensation is to reach our awareness, the second-order neuron synapses on a third-order neuron in the thalamus.
**Third-Order Neuron**

- Located in the thalamus, the third-order neuron projects up to the end of the line. Next stop, *cerebral cortex* (primary sensory area = *postcentral gyrus*)

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**Receptive Field**

- Area is monitored by a single receptor cell
- The **larger** the receptive field, the more difficult it is to localize a stimulus
Sensory map

• Sensory information from toes arrives at one end of the primary sensory cortex, while that from the head arrives at the other.

• When neurons in a specific portion of your primary sensory cortex are stimulated, you become aware of sensations originating at a specific location.

Sensory Homunculus

• Functional map of the primary sensory cortex
Sensory homunculus

- Distortions occur because area of sensory cortex devoted to particular body region is not proportional to region’s size, but to number of sensory receptors it contains.

Does size matter?

- How does receptive field size relate to cortical territory?
- Small field takes a lot of neurons (e.g. fingers) while large only takes fewer (e.g. back)
For all sensory pathways, the cell body of a first-order general sensory neuron is located in **dorsal root ganglion** or cranial nerve ganglion.
Strong Visceral Pain

• Sensations arriving at segment of spinal cord can stimulate “interneurons” that are part of the pain pathway
• Activity in interneurons leads to stimulation of primary sensory cortex, so an individual feels pain in specific part of body surface:
  – also called referred pain

Summary: Sensory

• Two neurons bring the somatic sensory information from the body to the third-order neurons in the thalamus for processing
• A small fraction of the arriving information is projected to the cerebral cortex and reaches our awareness
• Where the info goes in the brain determines how it is perceived (what type of sensation)
Somatic Motor Commands

• Issued by the CNS
• Distributed by peripheral nervous system (PNS) which includes the autonomic nervous system (ANS)
• Travel from motor centers in the brain along somatic motor pathways of tracts in the spinal cord and nerves of the PNS

Primary Motor Cortex

• Most complex and variable motor activities are directed by primary motor cortex of cerebral hemispheres
• The precentral gyrus has a motor homunculus that corresponds point-by-point with specific regions of the body
• Cortical areas have been mapped out in diagrammatic form
Motor homunculus: proportions

Similar to the sensory homunculus, but not exactly the same:

- hands, tongue, mouth HUGE; feet, genitals smaller
Motor Unit size and the homunculus

• How does the size of motor units within a muscle relate to the homunculus (that is, to the amount of cortical territory devoted to that muscle)?

Somatic Motor Commands

• Several centers in cerebrum, diencephalon, and brain stem may issue somatic motor commands as result of processing performed at subconscious level
Motor Pathways

• Consists of two neurons
  – Upper motor neuron (brain)
  – Lower motor neuron (spinal cord or brain stem)

Upper Motor Neuron

• Synapses on the lower motor neuron
• Innervates a single motor unit in a skeletal muscle:
  – activity in upper motor neuron may facilitate or inhibit lower motor neuron
• Problems with upper motor neurons (like stroke) usually eliminate voluntary control but NOT reflex movement
Lower Motor Neuron

• Triggers a contraction in innervated muscle
• Cell body in spinal cord ventral horn
• Only the axon of a lower motor neuron extends outside CNS as part of a spinal nerve
• What NT do lower motor neurons use?
• Destruction of or damage to lower motor neuron eliminates both voluntary and reflex control over innervated motor unit

Corticospinal Pathway

• Sometimes called the pyramidal system
• Provides voluntary control over skeletal muscles:
  – Upper motor neurons are in the primary motor cortex
  – axons of these upper motor neurons descend into brain stem and spinal cord to synapse on lower motor neurons in the spinal cord that control skeletal muscles
The Pyramids

- As they descend, corticospinal tracts are visible along the ventral surface of medulla oblongata as pair of thick bands, the pyramids
- Most fibers cross to the other side of the body in the pyramids

Basal Nuclei and Cerebellum

- Responsible for coordination and feedback control over muscle contractions, whether contractions are consciously or subconsciously directed
- Basal Nuclei:
  - Provide background patterns of movement involved in voluntary motor activities
  - Disrupted in PD and HD
- Cerebellum monitors:
  - proprioceptive (position) sensations
  - visual information from the eyes
  - vestibular (balance) sensations from inner ear as movements are under way
- Controls postural reflexes and complex motor activities
**Summary: Motor**

- Two neurons involved: upper motor neurons (often in the primary motor cortex) and lower motor neurons in the spinal cord or cranial nerve nuclei.
- Voluntary movement travels in the corticospinal tract while involuntary movements and postural reflexes travel in the medial and lateral pathways.
- The basal nuclei and cerebellum are involved in coordinating muscle contractions at a subconscious level.

**Spinal Cord Trauma: Paralysis**

- Paralysis – loss of motor function.
- Flaccid paralysis – severe damage to the ventral root or anterior horn cells.
  - Lower motor neurons are damaged and impulses do not reach muscles.
  - There is no voluntary or involuntary control of muscles.
Spinal Cord Trauma: Paralysis

• Spastic paralysis – only upper motor neurons of the primary motor cortex are damaged
  – Spinal neurons remain intact and muscles are stimulated irregularly
  – There is no voluntary control of muscles (but reflexes?)

Spinal Cord Trauma: Transection

• Cross sectioning of the spinal cord at any level results in total motor and sensory loss in regions inferior to the cut
• Paraplegia – transection between $T_1$ and $L_1$
• Quadriplegia – transection in the cervical region; how high determines the extent of the damage
Motor neuron diseases

• Poliomyelitis
  – Destruction of the anterior horn lower motor neurons by the poliovirus
  – Early symptoms – fever, headache, muscle pain and weakness, and loss of somatic reflexes
• Amyotrophic Lateral Sclerosis (ALS or Lou Gehrig’s disease)
  – Neuromuscular condition involving destruction of anterior horn motor neurons and fibers of the pyramidal tract
  – Loss of the ability to speak, swallow, and breathe
  – Death often occurs within five years
  – Some cases linked to malfunctioning genes for glutamate transporter and/or superoxide dismutase

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