Anatomy of the Spinal Cord

Neuroanatomy block-Anatomy-Lecture 2
Objectives

At the end of the lecture, students should be able to:

1. Describe the external anatomy of the spinal cord.
2. Describe the internal anatomy of the spinal cord.
3. Describe the spinal nerves: formation, branches & distribution via plexuses.
4. Define Dermatome and describe its significance.
5. Describe the meninges of the spinal cord.
6. Define a reflex and reflex arc, and describe the components of the reflex arc.

Color guide
- Only in boys slides in Green
- Only in girls slides in Purple
- Important in Red
- Notes in Grey
### Spinal cord

#### Function & Protection
- The primary function of spinal cord is a transmission of neural signals between the brain and the (PNS) then to the rest of the body by:
  1. Sensory.
  3. Local reflexes.
- Protected by **vertebrae** and surrounded by the **meninges** and cerebrospinal fluid (**CSF**).

#### Features
- Gives rise to 31 pairs of spinal nerves:
  - 8 Cervical, 12 Thoracic, 5 Lumbar, 5 Sacral, 1 Coccygeal.
- Spinal cord has two enlargements:
  - **Cervical enlargement**: supplies upper limbs.
  - **Lumbosacral enlargement**: supplies lower limbs.

#### Shape & Pathway
- It is elongated, cylindrical, thickness of the little finger, suspended in the vertebral canal.
- Continuous above with the **medulla oblongata**, extends from foramen magnum to 2nd lumbar (L1-L2) vertebra. (In children it extends to L3). In adults, its Length is approximately 45 cm.
- The tapered inferior end forms **Conus Medullaris**, which is connected to the coccyx by a non-neuronal cord called **Filum Terminale**.
- The bundle of spinal nerves extending inferiorly from lumbosacral enlargement and conus medullaris surround the filum terminale and form **cauda equina**.
The spinal cord is incompletely divided into two equal parts: anteriorly by a short, shallow median fissure. Posteriorly by a deep narrow septum, the posterior median septum.

Central canal
- A cerebrospinal-filled space that runs longitudinally through the entire length of the spinal cord.
- Lined by ependymal (ciliated columnar epithelium)
- Continuous with the ventricular system of the brain
- Superiorly opens into the 4th ventricle
- Inferiorly in the conus medullaris, it expands into the fusiform terminal ventricle and terminates below at the root of filum terminale.

Commissure
- Composed of grey matter in the centre surrounded by white matter supported by neuroglia.

Grey commissure:
1. A transverse bridge of grey matter connecting the anterior and posterior gray horns on each side
2. Is pierced by the central canal that divides it into anterior and posterior part.

White commissure:
1. Lies ventral to the gray commissure.
2. Mainly contains decussating nerve fibers.
Grey matter

- The arrangement of grey matter resembles the shape of the letter H, having two posterior, two anterior and two lateral horns/columns.
- Consists of nerve cell bodies and their processes, neuroglia, and blood vessels.
- The nerve cells are multipolar and are of three main categories:
  1. **Sensory neurons (Tract cells)**: receive impulses from the periphery of the body and whose axons constitute the ascending fasciculi of the white matter, are located in the Dorsal horns.
  2. **Lower motor neurons**: transmit impulses to the skeletal muscles, are located in the ventral horns (similar neurons in the lateral horn are the preganglionic neurons of the autonomic system).
  3. **Interneurons (connector neurons)**: linking sensory and motor neurons, at the same or different levels, which form spinal reflex arcs.

- **Arrangement of the nerve cells group:**

<table>
<thead>
<tr>
<th>Dorsal Horn</th>
<th>Ventral Horn</th>
<th>Lateral Horn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Substantia gelatinosa</td>
<td>1. Motor neurons, also called lower motor neurons.</td>
<td>Small column composed of small neurons extend from:</td>
</tr>
<tr>
<td>2. Nucleus proprius</td>
<td>2. Interneurons, the (Renshaw cells),</td>
<td>• T1 to L2-3 segments, give rise to preganglionic sympathetic fibers</td>
</tr>
<tr>
<td>3. Nucleus dorsalis (Clarke’s column, nucleus thoracis)</td>
<td></td>
<td>• S2-4 segments, give rise to preganglionic parasympathetic fibers</td>
</tr>
<tr>
<td>4. Visceral afferent nucleus.</td>
<td></td>
<td><strong>Intermediolateral Nucleus (IMN)</strong>: Located in the intermediate column and lateral horn. relays sensory information from visceral to the brain, and autoimmune signals from the brain to the visceral organs. (Lamine VII).</td>
</tr>
</tbody>
</table>
Neuronal architecture of spinal grey matter
(Rexed Laminae)

- The Rexed laminae comprise a system of ten layers of grey matter (I-X).
- These layers are called the Laminae of Rexed, that are numbered consecutively by Roman numerals, starting from the tip of the dorsal horn and moving ventrally into the ventral horn.
- Identified in the early 1950s by Swedish neuroscientist.
- Cells of the same type are clustered into groups, which occur in long columns.
- In transverse section, these columns appear as layers, especially within the dorsal horn.
# Groups of cells in the Dorsal Horn

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Function and features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal zone (MZ)</td>
<td>at the tip of the dorsal horn. (Laminae I)</td>
<td>Important for relaying pain and temperature sensation to the brain.</td>
</tr>
<tr>
<td>Substantia Gelatinosa (SG):</td>
<td>at the apex of the posterior horn (Laminae II).</td>
<td>Dorsal root fibers relaying pain, temperature, and light touch sensation to the brain. Composed of large neurons and Extends throughout the length of spinal cord</td>
</tr>
<tr>
<td>Nucleus Proprius (NP) (Nucleus Centralis):</td>
<td>in the neck of the dorsal horn (anterior to substantia gelatinosa) (Laminae IV).</td>
<td>Dorsal root fibers concerned with half of crude touch, concerned with senses of position &amp; movement. Composed of large neurons and Extends throughout the length of spinal cord</td>
</tr>
<tr>
<td>Nucleus Dorsalis (Clark's column, Nucleus thoracis)</td>
<td>at the base of dorsal horn (Laminae VII).</td>
<td>dorsal root fibers concerned with information from muscle spindles and tendon organs (relays unconscious proprioceptive information to the brain) Composed mostly of large neurons and Extends from C8 to L3-4 segments</td>
</tr>
<tr>
<td>Visceral Afferent Nucleus</td>
<td>lateral to nucleus dorsalis Rexed (Lamina VII)</td>
<td>• Afferents: Visceral afferents • Composed mostly of medium size neurons • Extends from T1 to L3 segments</td>
</tr>
</tbody>
</table>

*See the pic in the previous slide*
Groups of cells in the ventral horn

The ventral horns contain:

1. Motor neurons, also called lower motor neurons, and has two types:
   - Large multipolar cells ➢ Numerous ➢ Axons pass out in the ventral roots of spinal nerves as alpha efferents ➢ Innervate extrafusal muscle fibers
   - Smaller multipolar cells ➢ Less numerous ➢ Axons pass out in the ventral roots of spinal nerves as gamma efferents ➢ Innervate intrafusal muscle fibers of neuromuscular spindles

*Both alpha and gamma motor neurons are under the influence of descending pathways (upper motor neurons) from brain

Motor neurons are organized in 3 groups:
   a. **Medial**: present in most segments and innervate muscles of Neck and Trunk (including intercostal and abdominal muscles).
   b. **Central**: smallest, present in some segments: cervical (phrenic C3-5, spinal accessory C1-6) and lumbosacral (L2-S1).
   c. **Lateral**: present in cervical and lumbosacral segments, innervates muscles of the Limbs

*Lateral motor neurons and medial motor neurons: Composed of motor neurons that innervate visceral and skeletal muscles. (Laminae VIII & IX)

2. Interneurons, the (Renshaw cells), whose branched axons form inhibitory synaptic junctions on motor neurons
**White matter**

1. Consists of mixture of nerve fibers, neuroglia and blood vessels. White color is due to high proportion of *myelinated* nerve fibers.

2. The nerve fibers are arranged as bundles, running vertically through the cord. A group of axons that share a common origin, termination and function form a tract or fasciculus.

3. Arranged in columns/funiculi; anterior, posterior and lateral.

4. Tracts are often named according to their points of origin and destination, e.g. spinothalamic, corticospinal.

5. Depending on their functions, the spinal tracts are divided into *ascending tracts* and *descending tract*.

**Regional differences**

- The amount of white matter increases in a caudal-to-cranial direction because fibers are added to ascending tracts and fibers leave descending tracts.
- The gray matter is in increased volume in cervical & lumbosacral enlargements for innervation of upper & lower limbs.
- The lateral horn is characteristics of thoracic and upper lumbar segments.
Spinal nerves

- 31 pairs of spinal nerves. 8 pair cervical, 12 pair thoracic, 5 pair lumbar, 5 pair sacral, 1 pair coccygeal.
- First pair exit vertebral column between skull and atlas, last four pair exit via the sacral foramina and others exit through intervertebral foramina.
- Each spinal nerve arises as rootlets which then combine to form dorsal purely sensory & ventral purely motor Roots.
- Two roots merge laterally and form the spinal nerve.
- Dorsal root has a ganglion (dorsal root/sensory ganglion) that contains the cell bodies of the sensory neurons.
- Each spinal nerve then divides into a MIXED smaller dorsal and a larger ventral Ramus.

Branches of Spinal Nerves

| Dorsal Rami: | Innervate Deep muscles of the trunk responsible for movements of the vertebral column and Skin near the midline of the back. |
| Vental Rami: | In the thoracic region form Intercostal nerves that innervate the intercostal muscles and the skin over the thorax. Remaining ventral rami form five plexuses:  
  - C1 - C4 = Cervical plexus.  
  - C5 - T1 = Brachial plexus.  
  - L1 - L4 = Lumbar plexus.  
  - L4 - S4 = Sacral plexus.  
  - S5 & Co = Coccygeal plexus. |
| Communicating Rami | Is connection between spinal nerves and sympathetic chain of ganglia. |
Dermatome

- Dermatome is a segment of skin supplied by one spinal nerve. (segmental spinal nerve)
- Each of these spinal nerves relay sensation from a particular region of skin to the brain.
  - The nerves from the upper cervical spine supply the skin of the neck.
  - C5 to T1 nerves supply the arms.
  - T2 to L2 nerves supply the chest and abdomen.
  - L3 to S1 nerves supply the skin of the legs.
  - S1-Co nerves go to the groin.
- Cutaneous areas supplied by adjacent spinal nerves overlap. There is therefore little or no sensory loss after interruption of a single spinal nerve or dorsal root.
- Testing of dermatomes is part of the neurological examination looking for sensation changes within a specific dermatome that may help in determining the pathological disc level.

Spinal Meninges

- From outward to inward:
  
<table>
<thead>
<tr>
<th>Epidural space</th>
<th>Dura mater</th>
<th>Subdural space</th>
<th>Arachnoid mater</th>
<th>Subarachnoid</th>
<th>Pia mater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contains blood vessels, connective (areolar) tissue and fat</td>
<td>tough outer layer, continuous with epineurium of the spinal nerves</td>
<td>a potential cavity between the dura and arachnoid mater, Contains a small volume serous fluid</td>
<td>thin and wispy membrane deeper to dura mater</td>
<td>contain CSF and blood vessels within web-like strands of arachnoid tissue</td>
<td>delicate membrane bound tightly to surface of brain and spinal cord and carries blood vessels. Forms the filum terminale, which anchors spinal cord to coccyx and the denticulate ligaments that attach the spinal cord to the dura mater.</td>
</tr>
</tbody>
</table>
Reflex & Reflex arc

- A reflex is a rapid, involuntary, predictable response brought by a sensory stimulus.
- The neural pathway mediating the reflex actions is called reflex arc.
- Variety of Reflexes:
  - Some integrated within spinal cord; some within brain
  - Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action
  - Higher brain centers can influence, suppress, or exaggerate reflex responses

Components of a Reflex arc

1. Receptor
2. Sensory neuron
3. Integration center
4. Motor neuron
5. Effector
Q1: The tapered inferior end of the spinal cord forms:
A. denticulate ligaments
B. cauda equina.
C. conus medullaris.
D. filum terminale.

Q2: Which of the following nerve cell group will be missing in C8?
A. Visceral afferent nucleus.
B. Nucleus dorsalis.
C. Nucleus proprius.
D. Substantia gelatinosa.

Q3: The spinal cord is incompletely divided anteriorly into two equal parts by:
A. Posterior median septum.
B. Median fissure.
C. Cauda equina.
D. filum terminale.

Q4: Clarke's column (Nucleus dorsalis) present in which of the following horns?
A. Dorsal horn.
B. Ventral horn.
C. Lateral horn.
D. Anterior horn.

Q5: Which of the following is continuous with epineurium of the spinal nerves?
A. Pia mater.
B. arachnoid mater.
C. Dura mater.
D. subarachnoid space.

Q6: Brachial plexus is from C5 to .. ?
A. C6.
B. C7.
C. T1.
D. T2.

Q7: The spinal cord has:
A. 33 pairs of spinal nerves.
B. 31 spinal nerves.
C. 33 spinal nerves
D. 31 pairs of spinal nerves.

Q8: Only found in spinal segments C8 to L3-4.
A. Nucleus dorsalis.
B. Substantia gelatinosa.
C. Nucleus proprius.
D. Interomediolateral Nucleus.

Answers: Q1(C) Q2(A) Q3(B) Q4(A) Q5(C) Q6(C) Q7(D) Q8(A)
Members board

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Abdulrahman Shadid

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- Ali Aldawood
- Khalid Nagshabandi
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- Alwaleed Alsaleh
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- Alhanouf Al-haluli
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- Nouf Al Humaidhi
- Jude Al Khalifah
- Nouf Al Hussaini
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- Danah Al Halees
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