Chapter 15

The Nervous System

Sensory and Motor Tracts of the Spinal Cord

Lecture Presentation by
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Introduction

- Millions of sensory neurons are delivering information to the CNS all the time
- Millions of motor neurons are causing the body to respond in a variety of ways
- Sensory and motor neurons travel by different tracts within the spinal cord
Organization and Patterns of Spinal Cord Tracts

• Communication involves sensory and motor tracts
  • Ascending tract
    • Sensory (delivers information to the brain)
  • Descending tract
    • Motor (delivers information to the periphery)

• All tracts involve the spinal cord and the brain
Organization and Patterns of Spinal Cord Tracts

- Naming a tract often involves its origin and destination
  - Spinocerebellar tract
    - Origin is spinal cord and destination is cerebellum
  - Spinothalamic tract
    - Origin is spinal cord and destination is the thalamus
Organization and Patterns of Spinal Cord Tracts

• Naming a tract often involves its origin and destination
  • Corticospinal tract
    • Origin is cerebral cortex and destination is spinal cord
  • Vestibulospinal tract
    • Origin is vestibular nuclei and destination is spinal cord
Sensory Tracts

• There are three major sensory tracts
  • The posterior column
  • The spinothalamic tract
  • The spinocerebellar tract
• All three of these tracts are also called somatosensory tracts
Figure 15.1 A Cross-Sectional View Indicating the Locations of the Major Ascending (Sensory) Tracts in the Spinal Cord

- Dorsal root ganglion
- Dorsal root
- Ventral root
- Fasciculus gracilis
- Fasciculus cuneatus
- Posterior spinocerebellar tract
- Anterior spinocerebellar tract
- Lateral spinothalamic tract
- Anterior spinothalamic tract
- Posterior columns
Sensory Tracts

- **Posterior Column** consists of:
  - **Fasciculus gracilis**
    - Transmits information to the cerebrum coming from areas inferior to $T_6$
  - **Fasciculus cuneatus**
    - Transmits information to the cerebrum coming from areas superior to $T_6$
Sensory Tracts

• **Posterior Columns** (dorsal columns)
  • Transmits information such as:
    • Proprioception
    • Fine touch
    • Pressure
    • Vibration sensations
The posterior columns deliver fine-touch, vibration, and proprioception information to the primary sensory cortex of the cerebral hemisphere on the opposite side of the body. The crossover occurs in the medulla, after a synapse in the nucleus gracilis or nucleus cuneatus.
Sensory Tracts

• **The Spinothalamic Tract**
  • Transmits information such as:
    • Pain
    • Temperature
    • Crude sensations of touch and pressure
A sensory homunculus ("little human") is a functional map of the primary sensory cortex. The proportions are very different from those of the individual because the area of sensory cortex devoted to a particular body region is proportional to the number of sensory receptors it contains.

The anterior spinothalamic tract carries crude touch and pressure sensations to the primary sensory cortex on the opposite side of the body. The crossover occurs in the spinal cord at the level of entry.
The lateral spinothalamic tract carries sensations of pain and temperature to the primary sensory cortex on the opposite side of the body. The crossover occurs in the spinal cord, at the level of entry.
Sensory Tracts

• The Spinocerebellar Tracts
  • Transmits information such as:
    • Proprioception concerning muscles, tendons, and joints
The spinocerebellar tracts carry proprioceptive information to the cerebellum. (Only one tract is detailed on each side, although each side has both tracts.)
Sensory Tracts

• The three major sensory tracts involve chains of neurons
  • **First-order neuron**
    • Delivers sensations from the periphery to the CNS
  • **Second-order neuron**
    • Decussates to the contralateral side and ascends to the thalamus
  • **Third-order neuron**
    • Transmits information from the thalamus to the cerebral cortex
Sensory tracts that deliver somatic sensory information to the sensory cortex of the cerebral or cerebellar hemispheres involve a chain of neurons.

In most cases, the axon of either the first-order or second-order neuron crosses over to the opposite side of the spinal cord or brain stem as it ascends. As a result of this crossover, or decussation, sensory information from the left side of the body is delivered to the right side of the brain, and vice versa.

**First-Order Neuron**
A first-order neuron is the sensory neuron that delivers the sensations to the CNS; its cell body is in a dorsal root ganglion or a cranial nerve ganglion.

**Second-Order Neuron**
The axon of the first-order neuron synapses on a second-order neuron. The second-order neuron’s cell body may be located in either the spinal cord or the brain stem.

**Third-Order Neuron**
In tracts ending at the cerebral cortex, the second-order neuron synapses on a third-order neuron in the thalamus. The axon of the third-order neuron carries the sensory information from the thalamus to the appropriate sensory area of the cerebral cortex.

- **Sensory tract** in spinal cord
- **Dorsal root ganglion**
- **Somatic sensations from right side of the body**
- **Thalamus**
- **Brain stem**

**KEY**
- First-order neuron
- Second-order neuron
- Third-order neuron
Sensory Tracts

• Neurons in the sensory tracts are arranged according to three anatomical principles
  • Sensory modality
  • Medial–lateral rule
  • Somatotrophic
Sensory Tracts

• **Sensory Modality**
  • Fine touch sensations are carried in one sensory tract

• **Medial–Lateral Rule**
  • Sensory neurons that enter a low level of the spinal cord are more medial within the spinal cord
  • Sensory neurons that enter at a higher level of the spinal cord are more lateral within the spinal cord

• **Somatotopic**
  • Ascending tracts are arranged according to the site of origin
Neurons within the sensory tracts are not randomly arranged. Rather they are segregated, or arranged according to at least three anatomical principles:

1. **Sensory modality arrangement**
   - Sensory fibers are arranged within the spinal cord according to the type of sensory information carried by the individual neurons. In other words, information dealing with fine touch will be carried within one sensory tract, while information dealing with pain will be carried within another.

2. **Medial-lateral rule**
   - Most sensory nerves entering the spinal cord at more inferior levels travel more medially within a sensory tract than sensory nerves entering the cord at a more superior level. For instance, a sensory nerve that enters the cord at T₁₁ (11th thoracic spinal nerve) is located more medially within a sensory tract than a nerve that enters at C₄.

3. **Somatotopic arrangement**
   - Ascending sensory fibers are arranged within individual tracts according to their site of origin within the body. Sensory fibers coming from a particular region of the body, such as the upper limb, form a tract containing organized bundles of sensory fibers from the hand, wrist, forearm, and arm.
Motor Tracts

- **Motor Tracts**
  - CNS transmits motor commands in response to sensory information
  - These are descending tracts
  - Motor commands are delivered by the:
    - **Somatic nervous system** (SNS)
      - Directs contraction of skeletal muscles
    - **Autonomic nervous system** (ANS)
      - Directs the activity of glands, smooth muscles, and cardiac muscle
In the somatic nervous system (SNS), an upper-motor neuron in the CNS controls a lower-motor neuron in the brain stem or spinal cord. The axon of the lower-motor neuron has direct control over skeletal muscle fibers. Stimulation of the lower-motor neuron always has an excitatory effect on the skeletal muscle fibers.
In the autonomic nervous system (ANS), the axon of a preganglionic neuron in the CNS controls ganglionic neurons in the periphery. Stimulation of the ganglionic neurons may lead to excitation or inhibition of the visceral effector innervated.
Motor Tracts

• There are two principal motor tracts
  • **Corticospinal tract**: Conscious control of skeletal muscles
    • Corticobulbar, lateral corticospinal, and anterior corticospinal tracts
  • **Subconscious tract**: Subconscious regulation of balance, muscle tone, eye, hand, and upper limb position
    • Vestibulospinal, tectospinal, reticulospinal, and rubrospinal tracts
Motor Tracts

• The Corticospinal Tracts
  • Consists of three pairs of descending tracts
    • Corticobulbar tracts
      • Conscious control over eye, jaw, and face muscles
    • Lateral corticospinal tracts
      • Conscious control over skeletal muscles
    • Anterior corticospinal tracts
      • Conscious control over skeletal muscles
Figure 15.5 The Corticospinal Tracts

- Motor homunculus on primary motor cortex of left cerebral hemisphere

**KEY**
- Axon of upper-motor neuron
- Lower-motor neuron

- Corticobulbar tract
- To skeletal muscles
- Motor nuclei of cranial nerves
- To skeletal muscles
- Decussation of pyramids
- Lateral corticospinal tract
- To skeletal muscles

- Mesencephalon
- Cerebral peduncle
- Medulla oblongata
- Pyramids
- Anterior corticospinal tract
- Spinal cord
Neurons within the sensory tracts are not randomly arranged. Rather they are segregated, or arranged according to at least three anatomical principles:

1. **Sensory modality arrangement**
   - Sensory fibers are arranged within the spinal cord according to the type of sensory information carried by the individual neurons. In other words, information dealing with fine touch will be carried within one sensory tract, while information dealing with pain will be carried within another.

2. **Medial-lateral rule**
   - Most sensory nerves entering the spinal cord at more inferior levels travel more medially within a sensory tract than sensory nerves entering the cord at a more superior level. For instance, a sensory nerve that enters the cord at T11 (11th thoracic spinal nerve) is located more medially within a sensory tract than a nerve that enters at C4.

3. **Somatotopic arrangement**
   - Ascending sensory fibers are arranged within individual tracts according to their site of origin within the body. Sensory fibers coming from a particular region of the body, such as the upper limb, form a tract containing organized bundles of sensory fibers from the hand, wrist, forearm, and arm.
Motor Tracts

- **The Subconscious Motor Tracts**
  - Consists of four tracts involved in monitoring the subconscious motor control
    - Vestibulospinal tracts
    - Tectospinal tracts
    - Reticulospinal tracts
    - Rubrospinal tracts
Motor Tracts

- The Subconscious Motor Tracts
  - Vestibulospinal tracts
    - Send information from the inner ear to monitor position of the head
    - Vestibular nuclei respond by altering muscle tone, neck muscle contraction, and limbs for posture and balance
Motor Tracts

• The Subconscious Motor Tracts
  • **Tectospinal tracts**
    • Send information to the head, neck, and upper limbs in response to bright lights and sudden movements and loud noises
  • The tectum area consists of superior and inferior colliculi
    • **Superior colliculi**: receives visual information
    • **Inferior colliculi**: receives auditory information
Motor Tracts

• The Subconscious Motor Tracts
  • **Reticulospinal tracts**
    • Send information to cause eye movements and activate respiratory muscles
  • **Rubrospinal tracts**
    • Send information to the flexor and extensor muscles
Figure 15.6 Nuclei of Subconscious Motor Pathways

Basal Nuclei
- Caudate nucleus
- Putamen
- Globus pallidus

Other Structures
- Motor cortex
- Thalamus
- Superior colliculus
- Inferior colliculus
- Cerebellar nuclei
- Red nucleus
- Tectum
- Reticular formation
- Pons
- Vestibular nucleus
- Medulla oblongata

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Conscious and subconscious motor commands control skeletal muscles through descending motor tracts within the spinal cord.

**Motor Tracts Carrying Subconscious Motor Commands**

The **rubrospinal tract** automatically adjusts upper limb position and muscle tone during voluntary movements.

The **reticulospinal tract** originates in the reticular formation, a diffuse network of neurons in the brain stem. The functions of the tract vary depending on which area of the reticular formation is stimulated.

The **tectospinal tract** controls reflexive changes in position in response to auditory or visual stimuli.

The **vestibulospinal tract** carries motor commands that reflexively control posture and balance.

**Motor Tracts Carrying Conscious Motor Commands**

The **anterior corticospinal tract** contains axons that do not cross over (decussate) in the brain stem.

The **lateral corticospinal tract** contains the motor fibers that decussate within the brain stem.
Levels of Somatic Motor Control

- Somatic motor control involves:
  - Cerebral cortex
  - Basal nuclei
  - Cerebellum
  - Hypothalamus
  - Pons
  - Medulla oblongata
  - Brain stem and spinal cord
  - Thalamus
Somatic motor control involves a series of levels, with simple spinal and cranial reflexes at the bottom and complex voluntary motor patterns at the top.
Levels of Somatic Motor Control

• Summary of Somatic Motor Control
  • Cerebral cortex initiates voluntary movement
  • Information goes to the **basal nuclei** and **cerebellum**
    • These structures modify and coordinate the movements so they are performed in a smooth manner
The planning stage: When a conscious decision is made to perform a specific movement, information is relayed from the frontal lobes to motor association areas. These areas in turn relay the information to the cerebellum and basal nuclei.
Levels of Somatic Motor Control

• Summary of Somatic Motor Control
  • Information goes from:
    • The basal nuclei and cerebellum constantly monitor position and muscle tone
  • Information goes back to:
    • The cerebral cortex
  • Reason:
    • Constantly monitor position and muscle tone