Mechanisms & Neural Substrate of Spasticity

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Definition

- Spasticty - A velocity dependent increase in muscle tone (hypertonia) with exaggerated increase in reflexes (hyperreflexia).

- Hypertonia is associated with an increased resistance to passive stretch.

- Also associated with the clasp knife phenomenon and clonus.

- Caused by damage to descending pathways that influence gamma or alpha motor neurons.
Cerebral Cortex

Brain Stem

Spinal Cord

Effector Tissue

Skeletal Muscle of the Body

UMN (Alpha Motor Neurons)

LMN

Desc. Tracts to Spinal Cord

Interneurons
<table>
<thead>
<tr>
<th>LOWER MOTOR NEURON LESIONS</th>
<th>UPPER MOTOR NEURON LESIONS</th>
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</thead>
<tbody>
<tr>
<td><strong>CAUSES:</strong></td>
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<tr>
<td></td>
<td>1) Degeneration of Nerve Cell Bodies in the Motor / Somatosensory Cortices</td>
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<td>2) Damage to Axons of Descending Systems particularly Corticospinal Fibers</td>
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<tr>
<td><strong>SYMPTOMS:</strong></td>
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<tr>
<td>1) Flaccid Paralysis</td>
<td>1) Spastic Paralysis</td>
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<tr>
<td>2) Loss of Myotatic Reflexes</td>
<td>2) Hyperactive Myotatic Reflexes</td>
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<td>3) Hypotonia</td>
<td>3) Hypertonia</td>
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<tr>
<td>4) Muscle Fasciculations</td>
<td>4) Clonus</td>
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<tr>
<td>5) Atrophy of Denervated Muscles</td>
<td>5) Muscle Atrophy--if it occurs, it is very late and results from disuse</td>
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<td></td>
<td>6) Babinski Sign (Corticospinal Damage)</td>
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<td></td>
<td>7) Loss of Superficial Abdominal Reflex and Cremasteristic Reflex (males)</td>
</tr>
</tbody>
</table>
UMN/Descending Tracts Lesion

A. does NOT denervate target muscle

B. results in spastic paralysis
   1. resting tension of muscle is (hypertonia)
   2. hyperactive myotatic reflexes
   3. atrophy, if occurs, is a late event-from disuse of spastic muscle

LMN/Spinal Nerve Lesion

A. does denervate target muscle

B. results in flaccid paralysis
   1. absent or diminished muscle tone (hypotonia)
   2. loss of myotatic reflex
   3. atrophy of denervated muscle/s

Skeletal Muscle of the Body
The diagram illustrates the neural pathways involving the Cerebral Cortex, Cerebellum, Basal Ganglia, and Brain Stem Reticular Formation. It highlights cutaneous pathways and various neural structures such as Reticulospinal Tracts, dorsal root, DRG, la afferent fiber, Gamma Motor Neuron, Axon of Alpha Motor Neuron, PRST, Alpha Motor Neuron, MRST, Ventral Root, Spinal Nerve, and Extrafusal Muscle Fibers.
Flexors = dorsal in Lam. IX
Extensors = ventral in Lam. IX
Axial (Trunk) Muscles
Proximal Muscles
Distal Muscles
MEDIAL AND LATERAL DESCENDING SYSTEMS
Medial Descending Tracts

- Anterior Funiculus
  - Synapse in Lam. VII, VIII & IX (one tract)
  - Innervate axial & proximal muscles

Lateral Descending Tracts

- Lateral Funiculus
  - Synapse in Lam. V, VI, VII, VIII & IX (one tract)
  - Innervate distal muscles

UE=Flexors

UE=Extensors
Red Nucleus-Midbrain

RUBROSPINAL TRACT

RST
L. VESTIBULOSPINAL TRACT

Function: facilitates extension of all 4 extremities

Lateral Vestibular Nucleus (Pons)

LVST
M. VESTIBULOSPINAL TRACT

Function: controls neck movements to stabilize head for eye gaze movements

Medial Vestibular Nucleus (Medulla)

MVST
Function: controls muscle atonia during sleep
P. RETICULOSPINAL TRACT

Function: facilitates axial/proximal muscles

Reticular Formation (Pons)

PRST
• **AREA DAMAGED**: Transection of the Spinal Cord

• **STRUCTURES & TRACTS INVOLVED**:
  - 1) Disruption of all Spinal Cord Tracts

• **NEUROLOGICAL DEFICITS**:
  - 1) Period of Spinal Shock (Avg = 3 wks)
  - 2) Termination of Spinal Shock = Appearance of bilateral Babinski signs at ~ 3 wks
  - 3) Period of Minimal Reflex Activity (3-6 wks)
    a) muscles flaccid, no myotatic reflexes
    b) weak flexor responses that begin distally in response to noicoceptive stimuli
  - 4) Flexor Spasms (6-16 wks)
    a) Increasing tone in flexors and stronger flexor responses involving more proximal muscles in response to noicoceptive stimuli
    b) Triple Flexion Response is first seen and consists of flexion of the lower extremity at the hip, knee and ankle in response to mild noicoceptive stimulus
    c) Mass Reflex–powerful triple flexion reflex in response to non-specific stimulus
    d) Paradoxical sweating below lesion level
  - 5) Alternate Flexor & Extensor Spasms (4 mo-1 yr)
  - 6) Predominant Extensor Spasms (> 1 yr)
    a) marked extensor tone (spasticity & clasp-knife phenomenon)
    b) clonus
    c) bilateral Babinski signs
    d) loss of sensation below the lesion level
    e) increased myotatic reflexes
    f) bowel, bladder and sexual function disturbances
    g) reflex spinal sweating
Changes at the level of the spinal cord:

- Alpha motor neurons appear to be the most involved.
- Decrease in the amount of presynaptic inhibition of 1a afferents.
- Post activation repression of 1a afferents is decreased.
- Reciprocal 1a inhibition is reduced.
- Control of inhibitory interneurons impaired.
- Intraspinal sprouting.
Alpha Motor Neuron
Axon
D. Root Afferents
Excitatory Interneuron
Inhibitory Interneuron
Descending Tract
[1]
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Katz, 1999

Decrease in the amount of presynaptic inhibition of 1a afferents. Lack of this inhibition can contribute to increased stretch reflexes.
Reciprocal 1a inhibition is reduced
Reciprocal 1a inhibition is reduced.
Lesion above Spinal Cord

Lesion at Spinal Cord

Intraspinal sprouting.
Lack of corticospinal control
Abnormal descending influence
Abnormal afferent influence
Changes in inhibitory circuitry
- Lack of corticospinal control
- Abnormal descending influence
- Abnormal afferent influence
- Changes in inhibitory circuitry
The End!
Reciprocal 1a inhibition is reduced
Muscle Spindles

Muscle spindles consist of intrafusal fibers & specialized sensory and motor nerve fibers. These specialized fibers are anchored to the extrafusal muscle fibers and are stretched when the muscle is stretched. Responsible for the myotatic reflex.

Types of intrafusal fibers:
- Nuclear bag – responds to velocity & changes in muscle length (dynamic).
- Nuclear chain – responds to changes in muscle length (static).

Nerve supply:
- Sensory – Group 1a - Bag & Chain (dynamic).
- Motor – Gamma motor neurons – innervate ends of intrafusal fibers.
<table>
<thead>
<tr>
<th>DIFFERENCES</th>
<th>MEDIAL DESCENDING SYSTEM</th>
<th>LATERAL DESCENDING SYSTEM</th>
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<tbody>
<tr>
<td><strong>Funiculus</strong></td>
<td>Anterior Funiculus</td>
<td>Lateral Funiculus</td>
</tr>
<tr>
<td><strong>Target Cells</strong></td>
<td>Medial VII-IX</td>
<td>Lateral V-IX</td>
</tr>
<tr>
<td><strong>Pattern of Interneuron</strong></td>
<td>Long Axons</td>
<td>Short Axons</td>
</tr>
<tr>
<td>Projections</td>
<td>Many SC Seg.</td>
<td>Few SC Seg.</td>
</tr>
<tr>
<td><strong>Muscles Innervated</strong></td>
<td>Axial &amp; Proximal</td>
<td>Distal Limb Muscles</td>
</tr>
<tr>
<td><strong>Muscle Action</strong></td>
<td>FL.=UE; EXT.=LE</td>
<td>Ext.=UE; FL.=LE</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td>Posture</td>
<td>Skilled Move.</td>
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Post activation repression of 1a afferents is decreased.