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PHARMACOLOGY

The term somatosensory refers to bodily sensations of touch, pain, temperature, vibration, and proprioception (limb or joint position sense). The posterior column-medial lemniscal pathway conveys proprioception, vibration sense, and fine, discriminative touch. The anterolateral (or ventrolateral) pathways, include the spinothalamic tract and other associated tracts, convey pain, temperature sense, and crude touch. Since some aspects of touch sensation are carried by both pathways, touch sensation is not eliminated completely in isolated lesions to either pathway.

There are 4 types of sensory neuron fibers which are classified according to axon diameter. These different fiber types have specialized peripheral receptors that subserve different sensory modalities. Larger-diameter, myelinated axons conduct faster than smaller-diameter or unmyelinated axons. From largest to smallest diameter and conduction velocity, there are called A- alpha, A-beta, A-gamma, and unmyelinated C’s. They are detailed below along with their diameter, receptor type, and the sensory modality the serve.

Sensory neuron cell bodies are located in the dorsal root ganglia. Each dorsal root ganglion cell has a stem axon that bifurcates, resulting in one long axon that conveys sensory information from the periphery,

and a second axon that carries information to the spinal cord through the dorsal nerve roots.

2

A peripheral region innervated by sensory fibers from a single nerve root level is called a dermatome. Dermatomes for the different spinal levels form a map over the surface of the body. Sensation for the face is provided by the trigeminal nerve (CN V), while most of the remainder of the head is supplied by C2. The nipples are usually at the T4 level, while the umbilicus (“belly button”) is at approximately T10.

The shoulder, arms, and hands are represented in C5 through T1. The L4 and L5 representation extends over the anteriomedial shin and foot to the big toe. S1 and S2 innervate the back (dorsum) of the legs, and S3, S4, and S5 innervate the perineal area in a saddle-like distribution.

Just as the knowledge that the corticospinal tract crosses over at the pyramidal decussation helps us localize lesions, it is equally important to know

the points of decussation of the two major somatosensory pathways. The course of the two main somatosensory pathways will, therefore, be reviewed below.

Posterior Column-Medial Lemniscal Pathway. Large-diameter, myelinated axons carrying information about proprioception, vibration, and fine touch enter the spinal cord via the dorsal root entry zone. Most of these axons then enter the ipsilateral posterior columns to ascend all the way to the posterior column nuclei in the medulla. The most medial posterior column is called the fasciculus gracilis which carries sensory information from the legs and lower trunk. The more lateral fasciculus cuneatus carries information from the trunk above about T6, and from the arms and neck.

The first order neurons travel from the sensory receptor in the periphery, into the spinal cord, and then travel all the way up the cord in the posterior columns (fasciculus gracilis and cuneatus) to synapse onto second-order neurons in the nucleus gracilis and nucleus cuneatus located in the medulla.

Axons of these second-order neurons decussate as the internal arcuate fibers and then form the medial lemniscus on the other side of the medulla. The next major synapse occurs when the medial lemniscus axons terminate in the ventral posterior lateral nucleus (VPL) of the thalamus. The neurons of VPL then project through the posterior limb of the internal capsule in the thalamic somatosensory radiations to reach the primary somatosensory cortex in the postcentral gyrus.

An analogous pathway called the trigeminal lemniscus conveys touch and vibration sense for the face via the ventral posterior medial (VPM) nucleus of the thalamus to the primary somatosensory cortex. Synaptic inputs to the

3

primary somatosensory cortex from both the face and body occur mainly in cortical layer IV.

Spinothalamic Tract & Other Anterolateral Pathways. Smaller- diameter and unmyelinated axons carrying information about pain and temperature sense also enter the spinal cord via the dorsal root entry zone. However, in contrast to the posterior columns, these axons make their first synapses immediately in the gray matter of the spinal cord.

Second-order anterolateral sensory neurons in the central gray cross over in the spinal cord anterior (ventral) commissure to ascend in the anterolateral (ventrolateral) white matter.

The next major synaptic relay is, again, in the thalamus which projects to the primary somatosensory cortex (Brodmann’s areas 3,1, 2) via the posterior limb of the internal capsule. Pain and temperature sensation for the face is carried by an analogous pathway called the trigeminothalamic tract.

The anterolateral pathways consist of three tracts: the spinothalamic, spinoreticular, and spinomesencephalic tracts. The spinothalamic tract is the best known and mediates discriminative aspects of pain and temperature sensation, such as location and intensity of the stimulus. Like the posterior column-medial lemniscal pathway, the main relay for the spinothalamic tract is the ventral posterior lateral nucleus (VPL) of the thalamus. There are also some spinothalamic projections to other thalamic nuclei, including intralaminar thalamic nuclei and dorsal-medial nucleus.

The spinoreticular tract within the anterolateral pathways is a phylogenetically older pain pathway responsible for conveying the emotional and

4

arousal aspects of pain. The spinoreticular tract terminates on the medullary- pontine reticular formation, which in turn projects to the intralaminar thalamic nuclei (centromedian nucleus). Unlike the VPL which projects specifically in a somatotopic fashion to primary somatosensory cortex, the intralaminar nuclei project diffusely to the entire cerebral cortex and are thought to be involved in behavioral arousal.

The spinomesencephalic tract projects to the midbrain periaqueductal gray matter and the superior colliculi. The periaqueductal gray participates in central modulation of pain.

The anterolateral pathways also convey crude touch in addition to pain and temperature sensation, and thus, can help maintain sense of touch when damage to the posterior columns occurs.

To summarize the functions of the three tracts that make up the anterolateral pathway, if you step on a tack with you foot, your spinothalamic tract enables you to realize “something sharp is puncturing the sole of my foot”; your spinothalamic intralaminar projections and spinoreticular tract cause you to feel “ouch! That hurts!”; and your spinomesencephalic tract leads to pain modulation, allowing you eventually to think “aah, that feels better.”

The location of the spinal cord sensory and motor spinal cord pathways are depicted in the figure below (including some pathways not yet covered).

Note the ascending sensory pathways are shown on the left side, and the descending motor pathways are shown on the right side, of the figure although in reality both sides mediates both sensory and motor functions.

Somatosensory Cortex. From the thalamic VPL (body & neck) and VPM (face) nuclei, somatosensory information is conveyed to primary somatosensory cortex in the postcentral gyrus (Brodmann’s areas 3,1,2). Like primary motor cortex, primary somatosensory cortex is somatotopically organized, with the face represented most laterally and the leg most medially. Information from primary somatosensory cortex is conveyed to the secondary somatosensory cortex (SII) located with the Sylvian (lateral) fissure, along its superior margin in a region

5

called the parietal operculum. SII is also somatotopically arranged. Further possessing of somatosensory information occurs in association cortex of the superior parietal lobule, including Brodmann’s areas 5 and 7. Lesions of primary and association somatosensory regions produce characteristic deficits referred to as cortical sensory loss.

Central Modulation of Pain. Pain modulation involves interactions between local circuits at the level of the spinal cord dorsal horn and distal modulatory inputs.

In a mechanism called, gate control theory, sensory inputs from fast, large- diameter, non-pain A-beta fibers reduce pain transmission through the dorsal horn by blocking (or getting there first) the slower, unmyelinated C pain fibers. Thus, for example, transcutaneous electrical nerve stimulation (TENS) devices work to reduce chronic pain by activating A-beta fibers. This is also why shaking your hand after striking your thumb with a hammer temporarily helps relieve the pain.

The periaqueductal gray receives inputs from the hypothalamus, amygdala, and cortex, and inhibits pain transmission in the dorsal horn of the cord by stimulating release of serotonin (5-HT) from the raphe nuclei in the rostral ventral medulla (RVM) (see figure below). The RVM also sends inputs to the locus ceruleus, which in turn sends noradrenergic (NE) projections to modulate pain in the dorsal horn of the cord