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Proprioception

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Abstract

The term proprioception is used to describe the sensory information that contributes to the sense of position of self and movement. Body position is perceived both at the conscious and unconscious levels. The information of conscious proprioception is utilized to facilitate complex motor activity, while unconscious proprioception is important to coordinate basic posturing during sitting, standing and simple gait activities. Proprioception is based on a multi-component sensory system. There are various peripheral receptors that detect specific signals and major sensory afferent pathways which carry the information from the spinal cord up to the cortex. There are parallel pathways, some of which serve conscious proprioception, and others that serve subconscious proprioception. Conscious proprioception is relayed mostly by the dorsal column, and in part by the spinocervical tract. The goal here is to outline our current understanding of these complex neural pathways, starting from the peripheral receptors and working up towards the center of perception, the brain.

Definition of Proprioception

The term proprioception is used to describe the sensory information that contributes to the sense of position of self and movement. Sir Charles Bell named the “sixth sense” as the sense of the positions and actions of the limbs (McCloskey 1978). Sherrington (1906) first used the term proprioception to define the sense of body position. Body position is perceived both at the conscious and unconscious levels. The information of conscious proprioception is utilized to facilitate complex motor activity, while unconscious proprioception is important to coordinate basic posturing during sitting, standing and simple gait activities. Defects in the conscious proprioception system manifest as stumbling, although gait and posture may be normal. Defects anywhere along the unconscious proprioceptive pathways may be manifest as postural deficits or ataxia.

There is a long history of studies aimed at understanding the neural mechanisms of position sense perception. Today, it is believed that proprioception refers to 2 kinds of sensations: that of static limb position and of kinesthesia. Static position reflects the conscious recognition of the orientation of the different body parts, while kinesthesia is the conscious recognition of rates of movement. In general, impulses from receptors in the joints and surrounding tissues are synthesized into a picture of the body's position. The brain then functions to perceive this information. Unfortunately, however, the system for proprioception is not quite that simple. Rather, proprioception is based on a multi-component sensory system which includes: various types of peripheral receptors which detect specific signals and major sensory afferent pathways which carry the information from the spinal cord up to the cortex. (Johnson et al 2008)

Receptors of Proprioception

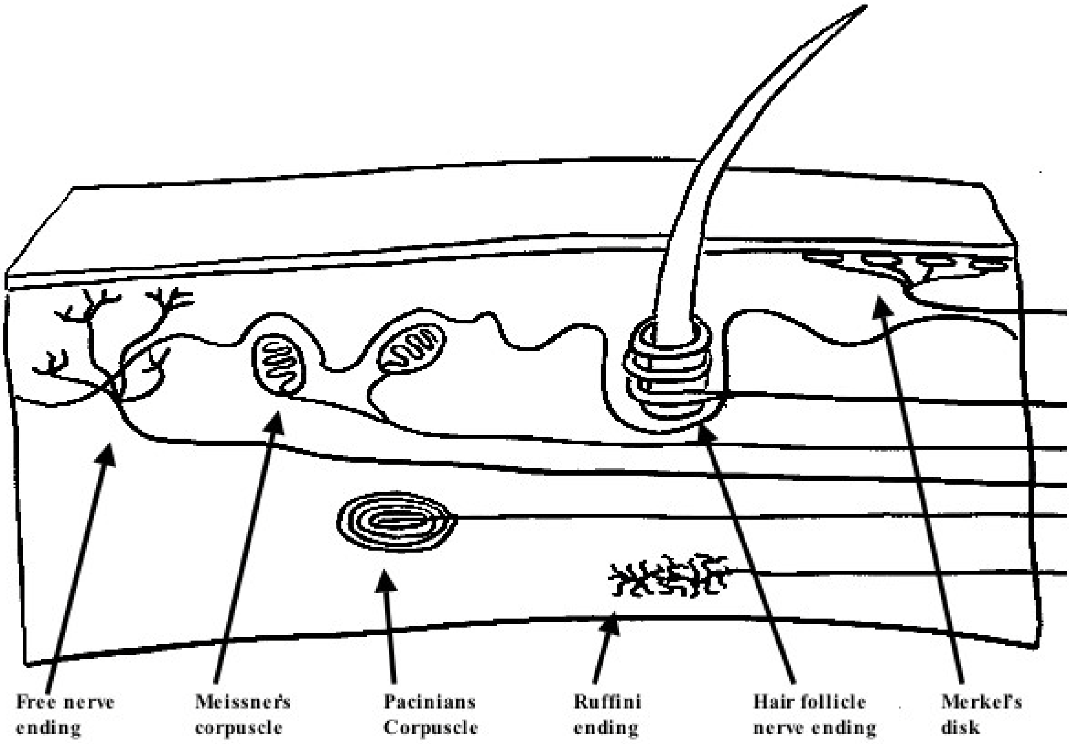
It is well recognized that joint movements activate receptors in the joint, skin and muscle. In turn, any of these receptors may play a role in the perception and control of limb movement and joint angle. Position sense has been associated with a distinct class of sensory receptors; particularly those found in the muscles and related deep tissues (Jami 1992). Kinesthesis has been associated with receptors located in joints and cutaneous tissue (Burgess et al. 1982).

A sensory unit is comprised of a stem fiber (a nerve fiber which forms the same kind of nerve ending at all of its terminals) and its family of endings. The territory from which a sensory unit can e excited is its receptive field.

Position sense is elicited by mechanical disturbances in the joints and surrounding tissues. These disturbances are first detected by mechanoreceptors and then, a given sensation, is signalled either by changes in the receptor's activity or by the number of receptors activated. Today, it is clear, that sensory information from several different types of receptors is used. These include extensive sensory endings, specific receptors, as well as muscle spindles. Free nerve endings are found throughout the substance of the ligaments and in the synovial covering. These transmit information on both joint position and movement. Of the Ruffini endings, the most abundant is this multi-branched encapsulated ending which is important for signalling the joint's limit of motion. Golgi-tendon like receptors are common around the knee joint. These encapsulated receptors signal information on tension. Pacinian corpuscles are usually dispersed in the surrounding tissues. They are easily recognized by their capsule, which surrounds a central nerve fiber. They detect rate of motion, and are stimulated by very minute and rapid movement.

Finally, two types of muscle spindles signal changes in muscle length. The flower spray ending relays static position information, and the annulospiral ending transmits mostly information regarding movement. It was believed that for the most part, kinesthesia sensations are detected by Pacinian corpuscles and Ruffini endings. However, it is now clear that muscle spindles, once thought to encode exclusively individual muscle lengths, are also major contributors to the kinesthetic sense of position and movement (Clark et al. 1985). Static limb position is mostly detected by flower spray muscle spindles and Golgi tendon organs.

Figure 1: Principal cutaneous receptors for position sense



Cutaneous receptors contribute to position and movement sense of the hand (Edin and Abbs 1991). In general, there are four types of mechanoreceptors of the glabrous hand, each with a different sensory function, which are responsible for proprioception of the hand. Slow adapting Type I receptors are essential for transmitting information regarding form and texture, while cutaneous rapid adapting receptors are important in grip control. The Pacinian system is related to the detection of distant events by vibrations through objects in the hand. Finally, the slow adapting type II receptor system relays information regarding hand conformation and perception of forces acting on the hand.

Sensory Innervation of Skin

Meissner's Corpuscles

The capsule of the Meissner corpuscle is comprised of an outer coat of connective tissue, a middle coat of perineural epithelium and an inner coat of modified Schwann cells (teloglia). Several axons zigzag among the stacks of teloglial lamellae in these ovoid-shaped receptors. As all encapsulated nerve endings it is a mechanoreceptor, which detects and transmits mechanical stimuli. Meissner's corpuscles are numerous in the finger pads. They respond to delicate tactile stimuli.

Pacinian corpuscles

The capsule of the Pacinian corpuscle is similar to that of the Meissner's corpuscle. Inside a thin connective sheath they show onion like layers of perineural epithelium which also contains a few capillaries. The innermost layer is comprised of several teloglial lamellae surrounding a single central axon that lacks a myelin sheath. The Pacinian corpuscle is about the size of rice grains, with about 300 in the hand. These subcutaneous receptors lie close to the underlying periosteum and along the sides of fingers, as well as in the palm. They are rapidly adapting mechanoreceptors and are particularly sensitive to vibration.

Ruffini endings

These encapsulated nerve endings are found in both hairy and glabrous skin. Their morphology is similar to that of Golgi tendon organs with a collagenous core and several axons branching out. These mechanoreceptors respond to shearing stress and are slowly adapting.

Merkel Disks

Merkel disks consist of expanded nerve terminals (tactile menisci) in the basal epithelium of epidermal pegs and ridges. These are slowly adapting receptors, which discharge continuously in response to sustained pressure.

Free nerve endings

Free nerve endings branch out in a subepidermal network. The sensory fiber at this point has lost its perineural sheath and myelin sheath (if any). The Schwann cell sheaths have opened to allow naked axons to terminate between collagen bundles or within the epidermis. Some sensory units are thermoreceptors, supplying either warm or cold spots. In addition, there are two types of nociceptors for pain transmission. The finely myelinaed A-delta parent fiber responds to severe mechanical deformation of the skin, while the C-fiber parent fibers are polymododal nociceptors that respond to mechanical deformation, intense heat and chemical irritants.

Follicular nerve endings

These are naked terminals that lie along the outer root sheath epithelium of the hair follicles just below the level of the sebaceous gland. Each follicular unit supplies several follicles.

Sensory Innervation of Skeletal Muscle

Neuromusclular spindles

These are found in skeletal muscle and are most abundant towards the tendinous attachment of the muscle. Each spindle is surrounded by a fusiform capsule of connective tissue, with slender intrafusal muscle fibers inside. There are two types of sensory innervation of muscle spindles: the *annulospiral* and the *flower spray*. The former are situated at the equator of the intrafusal fibers, where the unmyelinated axon winds spirally around the intrafusal fiber. The flower spray endings are found towards the ends of the spinal. In these nerve endings, the unmyelinated axon branches out terminally. Stretching of the intrafusal fibers results in stimulation of both the annulosprial and flower spray endings.

Golgi tendon organs (Neurotendinous spindles)

These are located in tendons and near the junctions of tendons with muscle. The spindle consists of a fibrous capsule that surrounds a small bundle of loosely arranged collagen fibers. A single I-beta nerve fiber forms complex sprays that intertwine with tendon fiber bundles.

The Peripheral Nerve - Mediators of Proprioception

Neurons are specialized cells that receive and send signals to other cells through their numerous extensions, axons and dendrites. Most neurons give rise to a single axon and many dendrites. Dendrites receive and transmit incoming synaptic information to the nerve cell body, whereas axons convey impulses from the neuron to its synpatic terminal (Johnson et al. 2005, Johnson et al. 2006). A peripheral nerve contains both dendrites and axons; fibers which conduct information to (afferent) or from (efferent) the CNS, respectively. Efferent fibers, for the most part axons, relay impulses related to motor function from the brain and spinal cord to muscles, glands, etc in the periphery. On the other hand, afferent fibers, mostly dendrites, usually convey sensory stimuli to the CNS via their nerve cell bodies in the spinal ganglia.

Table 1: Sensory fibers and receptors

Fiber	Diameter (nm)	Receptor	Function
A-alpha	10-20	nuclear bag intrafusal fibers	Changes in length & velocity muscle stretch
		Golgi tendon organ	Muscle & ligament tension
A-beta	4-12	nuclear bag chain fibers	Changes in length muscle stretch
		Meissner's corpuscle	Vibration & discriminative touch
		Pacinian corpuscle	Vibration & discriminative touch
		Merkel disk	Pressure on skin
		Ruffini's ending	Skin stretch
		Ruffini joint receptor	Range of motion (extremes)
		Pacinian joint receptor	Joint range of motion
A-delta	1-5	Free nerve endings	Crude touch, pain temperature
C	<1	Free nerve endings	Pain temperature

Spinal nerve contains both somatic and visceral fibers. The somatic component consists of efferent and afferent fibers. Efferent fibers innervate the skeletal muscles and are comprised mostly of axons of α, β, & γ neurons in the anterior grey column of the spinal cord. Afferent fibers, on the other hand, convey impulses to the CNS from various peripheral receptors and comprise the peripheral processes from unipolar cells in spinal ganglia. The visceral component of spinal nerves is also comprised of afferent and efferent fibers; these belong to the autonomic nervous system and include sympathetic and parasympathetic fibers at different spinal levels (Johnson et al. 2005, Johnson et al. 2006).

Spinal nerves are formed by the union of ventral and dorsal spinal nerve roots as they emerge through the intervertebral foramina. The ventral root contains axons from the cells of the anterior and lateral grey columns of the spinal cord. Each root emerges as a series of 2 to 8 rootlets arranged in 2 or 3 irregular rows over a distance of about 3 mm on the anterolateral aspect of the spinal cord. The ventral roots which constitute the motor outflow tracts from the spinal cord are comprised of large-diameter alpha motor neuron axons for the extrafusal striated muscle fibers; smaller gamma motor neuron axons that supply the intrafusal muscle of the muscle spindles; and a few small diameter axons (Johnson et al. 2006).

The dorsal root contains axons of cells in the spinal ganglia, and are fibers from cutaneous and deep structures. The largest fibers (Iα) come from muscle spindles and participate in spinal cord reflexes; the medium sized fibers (Aβ) convey impulse from mechanoreceptors in the skin and joints. Most of the axons in the dorsal nerve roots are small (C, nonmyelinated; A-delta, myelinated). Each root consists of 2 fascicles, medial and lateral, and diverges into rootlets that enter the cord along the posterolateral sulcus (Johnson et al. 2006).

The spinal ganglia are a collection of nerve cells on the dorsal root. Normally they are located within the intervertebral foramina, immediately lateral to the site where the nerve roots perforate the dura mater. Immediately beyond the spinal ganglia, the ventral and dorsal roots unite to form a spinal nerve and emerge through the intervertebral foramen. The spinal nerve gives off recurrent meningeal branches and then divides immediately into a dorsal and ventral ramus. At or immediately distal to its origin the ventral ramus of each spinal nerve is joined by a grey ramus communicans from the corresponding ganglion of the sympathetic trunk (Johnson et al. 2005).

The Transitional Zone Between the Peripheral – Central Nervous System

The sections of axons that comprise a nerve root are enclosed within a short glial segment that lies close to the surface of the spinal cord or brainstem when crossing the transitional zone between the central and peripheral nervous system. The transitional zone is that length of rootlet containing both central and peripheral nervous tissue. In man, this zone lays more peripherally in sensory nerves than in motor nerves.

The apex of the transitional region has been described as the glial dome with its convexity directed toward the periphery (Johnson et al. 2006). Electron microscopy has shown that the center of the dome consists of fibers showing typical central organization surrounded by an outer mantle of astrocytes (corresponding to the external glial limiting membrane). From this mantle, numerous process, the glial fringe, project into the endoneurial compartment of the peripheral nerve and interdigitate with the Schwann cells. Astrocytes form a loose meshwork through which the axons pass. It is not clear as to whether the basement membrane that surrounds the astrocytes is capable of preventing central Schwann cell migration.

In general, peripheral myelinated fibres cross the transitional zone at a node of Ranvier, termed a PNS-CNS compound node by Carlstedt and Berhold (Carlstedt and Berhold 1977). On the peripheral side of the node, the axon has a corona of Schwann cell microvilli and mitochondria-laden paranodal Schwann cell cytoplasm. The central side is characterized by a few astrocyte processes that typically make specialized contacts with the axolemma. Considerable rearrangement of axons occurs in the rootlets, and many of the largest non-myelinated peripheral axons become invested with a thin myelin sheath as they pass through this transitional region.

Sensory and Motor Connections with the Brain.

Multiple tracts connect many parts of the nervous system. Multiple ascending and descending tracts connect the PNS and lower spinal centers with the brain. This reflects that the nervous system is able to extract different pieces of sensory information from its surroundings and encode them separately, and that it is able to control specific aspect of motor behavior using different sets of neurons. The multiplicity of tracts endows the nervous system with a degree of redundancy. Thus, with partial destruction of nervous tissue, only some functions will be lost.

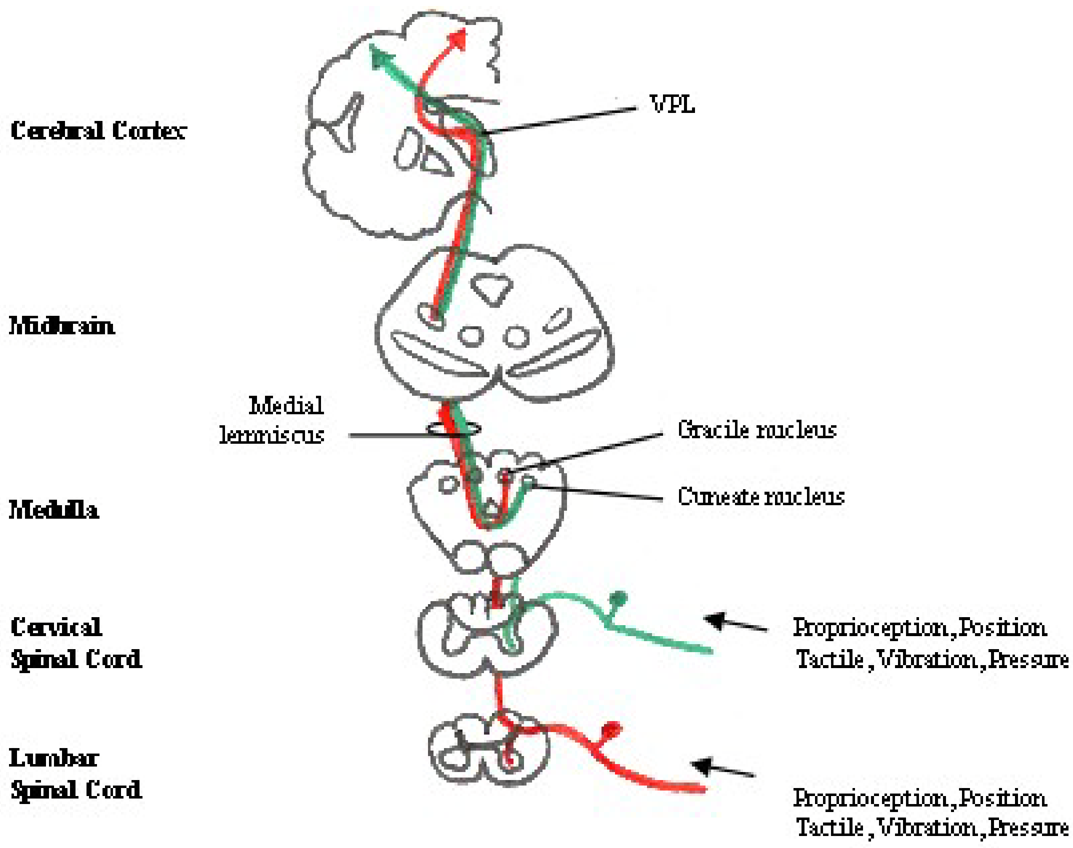
The nervous system is constructed with bilateral symmetry and with crossed representation. Although there are occasional exceptions to the pattern of crossed innervation, for the most part somatosensensory information (touch, temperature, joint position sense) from the body’s right side is processed in the somatosensory cortex in the left cerebral hemisphere. Similarly, the motor cortex of the left cerebral hemisphere controls body movements of the right side of the body. Of course there is one major exception to the rule of crossed motor control. Each cerebellar hemisphere controls coordination and muscle tone on the ipsilateral side of the body.

Examination of the major sensory or motor pathways reveals a highly and tightly organized nervous system. In particular, at each of many levels, we see fairly exact maps of the world within the brain. For example, sensory axons with within its ascending pathway are arranged in a very orderly manner, with fibers from specific anatomic locations (eg digits, hand, forearm, and so on) preserving very specific topographical locations with in the dorsal column, thalamus, internal capsule and sensory cortex.

Sensory Afferent Pathway of Proprioception

In general, impulses from peripheral receptors in the skin, muscles and joints are synthesized into a picture of the body's position, condition, etc. The brain then functions to perceive this information. Sensory perception is based on a multi-component sensory system that includes: various types of peripheral receptors which detect specific signals and major sensory afferent pathways which carry the information from the spinal cord up to the cortex. For the most part, conscious proprioceptive information is transmitted up the spinal cord in the dorsal colums and medial lemnisci to the cerebral cortex. This is not the only pathway system, however. There are also subconscious pathways with endpoints at the spinal cord, the cerebellum, as well as others in the cerebral cortex. In the conscious pathway, sensory information from receptors in the limbs and trunk is carried by peripheral nerves then the spinal cord via the fasciculus cuneatus and fasciculus gracillus to the brainstem where it crosses over to the contralateral cerebral cortex. The cortex then perceives and organizes precise information regarding the position and orientation of the limbs. In the unconscious proprioceptive pathway, sensory information from receptors in the limbs and trunk are transmitted via peripheral nerves to the spinocerebellar tracts where they information terminates on the ipsilateral cerebellum.

Figure 2: Primary somatosensory pathway that conveys fine discriminative touch, pressure, vibratory sensation, and conscious joint position sense



Sensory perception is elicited by disturbances in the skin, muscles, joints and surrounding tissues. These disturbances are first detected by mechanorecptors, pain receptor, temperature receptors, touch receptors etc and then, a given sensation, is signaled either by changes in the receptor's activity or by the number of receptors activated. Today, it is clear, that sensory information from several different types of receptors is used. Sensory fibers arise from pain, thermal, tactile and stretch receptors;

the cell bodies for these fibers are located within the dorsal root ganglia and their axons entering the posterolateral sulcus of the cord by way of several rootlets. For the most part, somatosensory information is transmitted up the spinal cord in the dorsal columns and medial lemnisci to the cerebral cortex. These tracts convey well-localized sensations of fine touch, vibration, two-point discrimination and proprioception from the skin and joints. This is not the only pathway system, however. There are also subconscious pathways with endpoints at the spinal cord, the cerebellum, as well as others in the cerebral cortex. (Johnson et al 2008).

On entering the spinal cord from the dorsal root, the fibers immediately divide to form a medial and lateral branch. The medial branch turns upward in the dorsal column and proceeds to the brain. The lateral branch divides in the same segment giving off terminals to the cord gray matter. These terminals serve 3 purposes: some give rise to the spinocervical tract that later joins the dorsal column, others give rise to tracts for the cerebellum, and others elicit local spinal reflexes.

At spinal cord entry, there is an anatomically distinct separation of modalities in specific regions of each spinal cord lamina. The dorsal column is the main afferent system. The dorsal column is formed by the medial branch that does not terminate in the spine. It transmits information regarding both movement and static position from Pacinian corpuscles. The spinocervical tract, on the other hand, is derived from those fibers that terminate in layer IV. This tract relays proprioceptive information regarding static position coming mostly from Ruffini endings, and this tract joins the dorsal column later on. Fibers conveying joint or position sense and some tactile fibers turn cephalad in the dorsal columns and do not synapse before reaching the gracile and cuneate nuclei at the cervicomedullary junction. Pain and temperature fibers synapse in the substantia gelatinosa and cross to ascend in the dorsal spinothalamic tract. Tactile fibers enter, synapse and cross to ascend in the ventral spinothalamic tract.

Somatosensory fibers ascend without crossing in the dorsal white column of the spinal cord to the lower brain stem. Immediately after entry into the spinal cord, the fibers of the dorsal column enter one of two white bundles. Fibers from the upper limb enter the fasciculus cuneatus, which lies between the fasciculs gracilis (which carries input from the lower half of the body) and the dorsal gray column. It is important to note that they ascend in the column, maintaining a distinct spatial orientation with respect to the body parts they were derived from. Fibers from the thoracic segments are more medial than the higher cervical fibers. Thus, one dorsal column contains fibers from all segments of the ipsilateral half of the body arranged in an orderly somatotopic fashion from medial to lateral. In the lower medulla, fibers from the upper extremity synapse with neurons of the cuneate nuclei. The new fibers from these neurons crossover immediately (lemniscal decussation) and then go on to form new afferent bundles, the medial lemnisci. The lemnisci ascend through the brainstem. By the time they reach the midbrain, the gracile portion that carries information regarding lower limb, has moved posterolateral to the cuneate.

All of these fibers synapse with the ventral posterolateral nucleus of the thalamus. This is a large cell mass that serves all somatic sensory modalities. The distinct spatial orientation is maintained in the thalamus, with the upper limb being represented by the most medial portion. However, because of the crossing over of fibers, the left side of the body is represented on the right side of the thalamus.

For all sensory systems, the thalamus acts as a crucial way station, much like a “check point Charlie”. That is, it intercepts all messages going to the cerebral cortex. Thus, the thalamus appears to "translate the information" before final processing by the cortex. New fibers from the thalamus enter the cerebral cortex via the posterior limb of the internal capsule. There the fibers synapse on the post-central gyrus of the parietal lobe (Luth et al. 1980, Mehler and Nauta 1974).

In the sensory cortex there is a point for point localization of peripheral areas. The size of the cortical receiving areas is porportionate to the number of receptors coming from that particular part of the body. This is represented by the sensory homunculus, a cartoon, which overlies a coronal section through the sensory gyrus. The proportions of the homuculus are distorted to correspond to the size of the cortical receiving area. The lower limb is located near the longitudinal fissure (Druschky et al. 2002, Sato et al. 2002).

Functionally, the neurons in the most anterior portion of the post-central gyrus respond to proprioceptive information. This indicates that this area is the cortical end-point for conscious proprioception. It is important to note the close anatomical relationship between the proprioceptive and motor cortex; the motor cortex which lies immediately anterior to the proprioceptive center.

Central Perception of Position Sense: What Does that Brain See?

The human brain has multiple body representations and basically, two body maps. One is the body schema, which codes the orientations of one’s body parts in space and time. The second is the body structural description, which codes the position of each body segment. Sense of position of body parts is a result of three inputs on the dorsal premotor cortex. These a three secondary inputs related to proprioceptive information which initially was transmited to the somatosensory cortex, visual information which was initially transmitted to the occipital cortex, and the combination of the vestibular system input from the bony labyrinth of the inner ear and tactile information from the somatosensory cortex. These pieces of information converge to the dorsal premotor cortex that ultimately is recognized as the primary site where sense of limb position contributes to controlled movement.

Most amputees experience phantom limb sensations and/or phantom limb pain that for the most part are resistant to management (Hunter et al 2005). Phantom limbs provide valuable information and insight into the proprioreceptive pathways underlying body position awareness. In general, phantom phenomena include spontaneous perceptions that usually generated by activation of thermoreceptors that signally warmth or coolness, deep or proprioceptive receptors which signal limb position, size, volume or movement and tingling sensations (Fraser et al 2001)

Various factors are related to the functional results following nerve repair, including: axonal growth, atrophy of targets, misdirection of regenerating axons, death of nerve cell bodies at dorsal root or spinal cord level, and functional reorganization of somatosensory cortex. Children show better results following nerve repair with no major differences in axonal regeneration. It is hypothesized that this may be related to superior brain plasticity in children. Today, the weight of the available evidence suggests that the organization of the sensorimotor cortex is not fixed, even in the adult brain, and that organizational changes in cortical regions can be produced.

Normally the hand is represented in areas 3b and 1 of the somatosensory cortex with the individual fingers being represented in well-defined bands (Sato et al 2002). A recent magnetoencephalography study provided evidence for a sequential topographical arrangement of not only the ventral, but also the dorsal surface representations of the individual digits in the human somatosensory cortex (Druschky et al 2002). Information regarding a topographic (homuncular) representation of the dorsal finger surfaces, and the sequential rostrocaudal array of the ventral finger aspects in the cortical area of 3b, might allow us to better understand cortical reorganization of the a subtly differentiated cortical map of the hand after peripheral nerve injury.

Recent evidence suggests that the organization of the sensorimotor cortex is not fixed and that organizational changes can be produced within these regions with external manipulations (Stefan et al 2000). A key factor in producing these organizational changes appears to be stereotyped afferent inputs. Motor cortex mapping has been used to study organizational changes in the motor cortex associated with peripheral sensory stimulation (Hamdy et al 1998), limb amputation and ischaemic nerve block (Cohen et al 1991, Brasil-Neto et al 1992) and motor learning (Pascual-Leone et al 1995). Moreover, a period of peripheral stimulation can induce striking organizational changes with the motor cortex (Ridding et al 2000, Ridding and Rothwell 1995).

PET (Positron emission tomography) has shown functional plasticity by showing an increase in projections in sensory and motor cortex with new uses of the fingers. Pascual-Leone and colleague (Pascual-Leone et al 1995) showed this in blind people learning to read Braile with increased projection of the reading finger.

Following medial nerve transection, the hand is partly denervated. However, we forget that the sensory cortex is also denervated, in part, due to the absence of sensory input. Primate studies have shown that after transection, a black hole in the sensory cortex develops corresponding to the sensory territory of the nerve. Soon following the transection (or repair) this area becomes occupied by substitute tactile input from adjacent hand areas that remain innervated by other nerves (cortical reorganization)(Lemon et al 2004, Nakajima et al 2000). When regenerating axons make peripheral connections, again there is a functional cortical reorganization. Sometimes this entails a total functional reorganization of the somatosensory cortex. This implies that the hand “speaks” a new language to the brain.

Assessment of Proprioception

Proprioception includes two components, the sense of stationary position of the limbs (limb position sense) and the sense of limb movement (kinaesthesia). Each component can be clinically tested individually, and give important information regarding specific cutaneous sensory receptors, peripheral nerves, dorsal roots, and central nervous system pathways. (Gilman 2002)

A thorough patient history often provides the clinician clues of the type of sensory disturbance. Pain, paraesthesias, tingling, numbness are often related to pain and temperature sensations involving smaller diameter fibers, and not fibers related to position sense or vibration sense. On the other hand, stumbling, difficulty standing straight when eyes are closed, uncoordinated use of the upper limb and hands, pseudoathetosis (involuntary movements of limbs when eyes are closed) suggest abnormalities of position sense or vibration sense. The clinician should use both static and dynamic stimuli to assess joint position sense. Joint position sense is evaluated by having the individul experience a specific joint position (angle) and then reproduce the position actively or react during passive movement. The joint position test measures the accuracy of position replication and can be conducted actively or passively in both open and closed kinetic chain positions. Joint kinaesthesia is determined by establishing a threshold at which motion is detected during various velocities and ranges of movement. Kinesthesia testing can be conducted by using the criterion of threshold to detection of passive motion direction, where the test assesses one's ability to not only detect motion, but also detect the direction the motion is occurring.

Several testing techniques and instrumentation have been used to assess the conscious submodalities of proprioception (joint position sense, kinaesthesia and sense of tension). Among the growing variety of equipment include commercial isokinetic dynamometers, electromagnetic tracking devices and custom-made jigs, for measuring conscious appreciation of proprioception.

Current evidence suggests that aging results in diverse declines in the morphology and physiological function of various sensory structures, preferential loss of distal large myelinated sensory fibers and receptors and impaired distal lower-extremity proprioception, vibration and discriminative touch and balance. (Shaffer and Harrison 2007) This suggests the need of refining sensory measures (vibration, 2-point discrimination and proprioception testing) in order to accurately assess the functin of large myelinated fibers in older patients.

Conclusion

Proprioception is the sense of body position that is perceived both at the conscious and unconscious levels. Typically, it refers to 2 kinds of sensations: that of static limb position and of kinesthesia. Static position reflects the recognition of the orientation of the different body parts, while kinesthesia is the recognition of rates of movement. Proprioception is based on a multi-component sensory system. There are various peripheral receptors, which detect specific signals and major sensory afferent pathways which carry the information from the spinal cord up to the cortex. There are parallel pathways, some of which serve conscious proprioception, and others that serve subconscious proprioception. Conscious proprioception is relayed mostly by the dorsal column, and in part by the spinocervical tract. Finally, the organ of perception for position sense is the sensory cortex of the brain.

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