NNAM PRECIOUS CHINONYE

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NURSING SCIENCE

200 LEVEL

PHS212

Describe the physiology of balance

The vestibular system is a complex set of structures and neural pathways that serves a wide variety of functions that contribute to our sense of proprioception and equilibrium.

These functions include the sensation of orientation and acceleration of the head in any direction with associated compensation in eye movement and posture. These reflexes are referred to as the vestibulo-ocular and vestibulospinal reflexes, respectively. The centrally located vestibular system involves neural pathways in the brain that respond to afferent input from the peripheral vestibular system in the inner ear and provide efferent signals that make these reflexes possible. Current data suggest that the vestibular system also plays a role in consciousness, and dysfunctions of the system can cause cognitive deficits related to spatial memory, learning, and navigation.

There are vast amounts of both afferent and efferent cellular connections involved in the vestibular system. Most of the afferent nerve signals come from the peripheral vestibular system found in the inner ear within the petrous temporal bone.

The inner ear contains;

* membranous labyrinth

*bony labyrinth

The bony labyrinth is filled with a fluid known as "perilymph" which is comparable to cerebrospinal fluid and drains into the subarachnoid space. Suspended within the bony labyrinth is the membranous labyrinth that contains a fluid known as “endolymph” unique in composition due to its high potassium ion concentration. Endolymph in the vestibular system is produced by the Vestibular Dark Cells which are similar to the Stria vascularis of the cochlea. Endolymph within the membranous labyrinth surrounds the sensory epithelium and interacts with hair cells within the vestibular apparatus providing the high potassium gradient to facilitate depolarization of the hair cell and afferent nerve transmission.

Vestibular apparatus

The vestibular apparatus comprises the utricle, saccule, and superior, posterior, and lateral semicircular ducts. The sensory neuroepithelium in the utricle and saccule is the macula, and the sensory neuroepithelium in the semicircular ducts is the crista ampullaris.

Both neuroepithelial structures contain specialized mechanoreceptor cells called "hair cells."

Hair cells contain a vast number of cross-linked actin filaments called stereocilia that are connected at the tips by “tip links.” The stereocilia contain cation channels at their apex and are organized in rows by length, with the tallest stereocilium connected to an immobile kinocilium.

Hair cells are divided into Type 1 hair cells and Type 2 hair cells.

Type 1 hair cells have a high variability of resting discharge while Type 2 hair cells have a low variability of resting discharge. Acceleration of endolymph results in the movement of stereocilia, leading to either depolarization or hyperpolarization depending on the direction of the inertial drag. Movement towards the kinocilium causes the interconnected tip links to pull open cation channels resulting in an influx of potassium ions and depolarization. The depolarized hair cell releases glutamate to afferent nerve receptors and neurotransmission to the vestibular ganglion. The vestibular ganglion, also known as Scarpa ganglion, contains thousands of bipolar neurons that receive sensory input from hair cells within the macula and crista ampullaris.

The vestibular nerve then joins the cochlear nerve to become cranial nerve VIII, the vestibulocochlear nerve. Afferent nerve signals carried by the vestibulocochlear nerve are then interpreted by the central vestibular system within the brain. The central vestibular system unites the peripheral signals from both ascending pathways to elicit eye, head, and body motor responses for control of balance and orientation

MECHANISM

The mechanism involved with the function of the peripheral vestibular system involves the acceleration of endolymph within the various structures of the vestibular apparatus.

Head movement in various directions is responsible for this acceleration that results in the stimulation of the stereocilia of hair cells,when the head stops accelerating, hair cells return to their baseline position which allows them to respond to further changes in endolymph acceleration.

Depending on the direction of acceleration, the inertial drag of the endolymph will push the stereocilia either towards or away from the fixed kinocilium,movement towards the kinocilium causes tip links to pull open cation channels resulting in depolarization of the hair cell via potassium ion influx.

Movement away from the kinocilium results in closure of the cation channels and hyperpolarization and reduction in afferent firing rates. Depolarization results in the opening of calcium channels. Calcium channel opening results in neurotransmitter release across the synaptic cleft, leading to nerve transmission to the vestibular ganglion.

FUNCTIONS

The vestibular system functions to detect the position and movement of our head in space; This allows for the coordination of eye movements, posture, and equilibrium.

The vestibular apparatus found in the inner ear helps to accomplish this task by sending afferent nerve signals from its individual components. The utricle and the saccule are responsible for sensing linear acceleration, gravitational forces, and tilting of the head. The neuroepithelium found in the utricle and saccule is the macula which provides neural feedback about horizontal motion from the utricle and vertical motion from the saccule. Embedded within the otolithic membrane of the macula are small calcium carbonate crystals known as otoliths that assist in hair cell response to the inertial drag of endolymph.

Angular acceleration and rotation of the head in various planes are sensed by the three semicircular ducts that are oriented at right angles to one another. Each of the semicircular ducts contains a dilation near the opening to the utricle. This dilation is called the ampulla which contains a neuroepithelial structure called the "crista ampullaris."

The crista ampullaris is coated by a gelatinous protein-polysaccharide substance known as the cupula which holds the hair cells in place. Unlike the macula, the crista ampullaris does not contain otoliths. In addition to the functions associated with the peripheral vestibular system, the central vestibular system allows for processing and interpretation of afferent signals and the output of efferent signals.

Efferent signals includes:

* vestibulo-ocular reflex:

Allows the eyes to remain fixed on an object while the head is moving,this is accomplished by coordinating movement between both eyes involving the parapontine reticular formation and output to various extraocular eye muscles involving the oculomotor and abducens nerves.

* The vestibulospinal reflex :

Maintains balance and posture through the coordination of spinal musculature with head movement. Cognitive functions that involve the central vestibular system are based on established neural pathways, although many pathways are still unknown. The known central vestibular connections include the vestibulo-thalamo-cortical tract, dorsal tegmental nucleus to entorhinal cortex tract, and nucleus reticularis pontis oralis to hippocampus tract. These tracts form a series of complex connections that play a functional role in self-motion perception, spatial navigation, spatial memory, and object recognition memory.

Clinical pathology

Dysfunction of the vestibular system can manifest symptomatically as vertigo, nausea, vomiting, visual disturbance, hearing changes, and various cognitive deficits. many patients with vestibular dysfunction exhibit impairment of spatial navigation, learning, memory, and object recognition.

The pathophysiology of vertigo can be defined as peripheral or central. Peripheral vertigo is more common than central vertigo

three of the most common etiologies includes:

*benign paroxysmal positional vertigo

* Meniere disease,

*viral labyrinthitis.

(a)Benign paroxysmal positional vertigo (BPPV) is the most common cause of peripheral vertigo and lasts for seconds to minutes. Most cases are idiopathic but the pathophysiology is believed to be due to displaced otoconia in the posterior semicircular canal that causes an inappropriate sensation of movement. BPPV is diagnosed based on a thorough history and use of the Dix-Hallpike test with associated reproduction of vertigo symptoms and nystagmus. There are many movement techniques used to treat BPPV; however, the Epley maneuver is often cited as being one of the most effective. The technique involves rotating and tilting the head and body in various ways to reposition displaced otoconia in the inner ear. For acute, severe exacerbations of BPPV, anti-vertigo medications are indicated to help with symptom control.

(b)Meniere disease is another cause of peripheral vertigo that can last for hours and also manifest with symptoms of hearing loss and tinnitus. The pathophysiology of Meniere disease is the expansion of endolymph volume within the membranous labyrinth. This volume expansion impacts both the vestibular apparatus and cochlea that are both filled with endolymph. Expansion of endolymph within the cochlear duct results in defects in hearing that differentiate it from BPPV. Meniere disease is diagnosed based on clinical criteria, and currently, no curative treatments exist. Symptoms are managed with anti-vertigo medications, low-salt diet, and surgical decompression of the endolymphatic sac.