Vestibular System
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OBJECTIVES

After studying the material of this lecture, the student should be able to:
1. Understand the structure of the membranous labyrinth and vestibular end organs: ampullae of the semicircular canals and maculae of the otolith organs (saccule and utricle)
2. Understand the central connections of the vestibular nerve (C.N. VIII) and vestibular complex, and their roles in the vestibuloocular and vestibulocollic reflexes and in the control of posture.
3. Appreciate the clinical deficits that occur as a result of vestibular lesions.

I. INTRODUCTION

The vestibular end-organs sense changes in the position and movement of the head in the three dimensions of space. Their hair cell receptors in the ampullae of the semicircular canals and maculae of the otolith organs (saccule and utricle) are innervated by the peripheral processes of bipolar neurons in the vestibular (Scarpa’s) ganglion. The central processes of these first-order neurons form the vestibular division of the vestibulocochlear (VIII) nerve and terminate in the vestibular complex in the dorsolateral medulla. Second-order vestibular neurons transform vestibular signals (with the aid of the cerebellum, proprioceptive and visual sensory signals) into motor commands that are relayed through ascending and descending connections with extraocular motor nuclei in the brainstem and motoneurons in the cervical spinal cord and have an important functional role in the control of gaze (eye and head movement). Other second-order vestibular neurons project to the medial part of the ventral horn for the entire length of the spinal cord for control of posture.

CNS Tracts That Mediate Vestibular Function:

Medial Longitudinal Fasciculus (ascending MLF to extraocular nuclei) - coordinates eye movements when head moves—vestibuloocular reflex (VOR)

Medial Vestibulospinal Tract (descending MLF to cervical spinal cord) – coordinates head movements with changes in body position -- vestibulocollie reflex

Lateral Vestibulospinal Tract -- maintains body posture and balance (equilibrium)

II. RECEPTORS

The receptor end organs for vestibular sensation (semicircular canals and otolith organs) are located within the petrous portion of the temporal bone adjacent to the cochlea.
Semicircular canals -- three planes (ant., post., horizontal) -- angular acceleration; detect angular head movements; *crista ampullaris* has *cupula* (gelatinous cap) on stereocilia and kinocilium; endolymph flow produces displacement of cupula, bending cilia -- results in generation of vestibular sensation (activation or inhibition depending on direction of bending).

Otolith organs- *saccule* and *utricle*-- gravitation (head position)/ linear acceleration; detect linear head movements; *macula* (gelatinous mass) with otoconia (calcium carbonate granules) over “hair cells” displace cilia to produce linear vestibular sensation.
III. FIRST-ORDER NEURONS

The first-order neurons of the vestibular pathway are bipolar cells in the vestibular (Scarpa’s) ganglion. Their peripheral processes end on vestibular “hair cells,” of the crista ampullaris and maculae of the saccule and utricle, while their central processes enter the brainstem with vestibular division of the vestibulocochlear nerve (C.N. VIII) to terminate in all subdivisions of the vestibular complex. A few primary vestibular fibers go directly to the flocculonodular lobe of the cerebellum ("vestibulocerebellum") via the juxtaestiform body (part of inf. cerebellar peduncle).
IV. SECOND-ORDER NEURONS

Second-order vestibular neurons have their cell bodies in the vestibular complex and give rise to ascending and descending projections:

A. Medial Longitudinal Fasciculus -- sup./med. vestibular nuclei give rise to ascending fibers in the MLF that project bilaterally to extraocular motor nuclei (III, IV, and VI) -- vestibuloocular reflex -- produces compensatory eye movements to stabilize image on fovea of retina during head movements
B. Vestibulospinal Tracts:

**Medial vestibulospinal tract** -- descending component of the MLF; med./inf. vestibular nuclei project bilaterally (crossed and uncrossed) to medial part of ventral horn of the **cervical spinal cord only** -- **vestibulocollic reflex**; produces compensatory head movements during changes of body position

**Lateral vestibulospinal tract** -- lateral vestibular nucleus -- projects ipsilaterally to the medial part of ventral horn (lamina VIII) **entire length of cord**- for posture; maintain extensor tone.
V. VESTIBULAR CONNECTIONS WITH THE CEREBELLUM

The **flocculonodular lobe** of the cerebellum (flocculus & nodule) is the **vestibulocerebellum**. The cerebellar fastigial nucleus has reciprocal connections with the flocculonodular lobe and the vestibular complex (via the JRB).

Primary vestibular fibers -- some primary vestibular afferents (central processes of first-order bipolar neurons whose cell bodies are in the vestibular ganglion, traveling in the vestibular division of the VIIIth nerve) pass thru the juxtarestiform body (part of the inf. cerebellar peduncle) directly to the flocculonodular lobe without first synapsing in the vestibular complex.
Second-Order Vestibular Fibers -- the vestibular complex has reciprocal connections with the flocculonodular lobe and with the fastigial nucleus thru the juxtaarestiform body.

Cerebello-Vestibular Connections:
VI. CLINICAL CORRELATIONS

Lesions of Vestibular Structures - MLF, flocculonodular lobe of the cerebellum

**Nystagmus** -- rhythmic involuntary oscillation of the eyes; the eyes move slowly to one side until they reach a limit, then jerk quickly to the opposite side. The direction of nystagmus is designated by the direction of the fast component. During head rotation, the fast phase is in the direction of rotation.

**Vertigo** - dizziness; sense of room spinning

Caloric Test - (caloric nystagmus) in normal subjects, cold water irrigation of the external auditory meatus results in nystagmus to the opposite side; warm water, nystagmus to the same side (COWS)

Lesions of vestibular system result in nystagmus and vertigo (dizziness): vestibular nerve (CN VIII), MLF, or flocculonodular lobe.

A Self-Assessment is available for this lecture.

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