Vestibular Anatomy & Physiology

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Overview

- Anatomy: 1) labyrinth, 2) vestibular nerve, 3) vestibular nuclei & brainstem, 4) cerebellum, 5) thalamus & basal ganglia, and cerebrum
- Function: detect position in space and coordinate posture and position of head, neck, and movement of eyes

The Labyrinth

- SCC: orientation, endolymph & cupula
    - Cilia bend leading to neuronal activation or inhibition
    - Detect angular acceleration
- Otolithic organs → utricle and saccule: curved like ellipsoids to detect 3 dimensions
    - Maculae hair cells embedded in gelatinous membrane with otoconia on top
    - Detect linear acceleration & position of head because of gravity
- Clinical relevance **BPPV**: Flourens' law & Ewald's first law → each canal produces movements of eye in plane of canal (upbeating / ipsitorsional, horizontal, downbeating contratorsional), thus [PEARL] pure vertical nystagmus can only be induced by simult stim of bilat canal and should think central; pure torsional only induced by simult stim of both vertical canals on same side and should think central
- Clinical relevance **AICA stroke**: supplies vestibule and cochlea and thus causes a peripheral hearing loss and vertigo

The Vestibular Nerve

- Crista and maculae pass thru lamina cribrosa → Scarpa's ganglion
- 8th nerve: cocclear and vestibular → passes medially traversing CPA posterior cochlear nerve and below facial nerve
    - Superior transmits anterior and lateral SCC & utricle
        - Runs with facial nerve
    - Inferior transmits posterior SCC & saccule
        - Runs with cochlear nerve
    - Enters brainstem b/w inferior cerebellar peduncle and spinal trigeminal
    - Synapses on vestibular nuclei
- Clinical relevance:
    - **Vestibular neuritis** → Ewald's second law: excitation better stimulus than inhibition
    - **Viral infections** tend to affect superior division w/ facial nerve
    - **Meningitis** (a disease of meninges in subarach space) commonly affects CN8 first
    - **Bilateral vestibular loss:** such as from gentamicin, poor signal on both sides (oscillopsia, unsteadiness)

The Vestibular Nuclei & Brainstem

- Brainstem: midbrain, pons, medulla
    - Midbrain connections: thalamus and remaining cortex superior
    - Pons: cerebellum is connected dorsally; vestibular nuclei

    - Medulla: vestibular nuclei
- Vestibular nuclei and tracts
    - Medial, lateral, superior, and inferior
    - Lateral vestibulospinal tract: maintains balance/tone (from lateral)
    - medial vestibulospinal tract: head & neck position (from medial & inferior)
    - medial longitudinal fasciculus (medial & superior nuclei) → mediates vestibulo-ocular reflex connecting w/ CN 3, 4, & 6
    - Vestibulocerebellar tract: joins in cerebellum for fine tuning
- Clinical relevance: **Hemorrhage, stroke, tumor**
    - Notably run with many structures responsible for diplopia, visual changes, somatosensory changes, weakness, dysarthria, incoordination, impaired consciousness
- Nucleus prepositus hypoglossi & interstitial nucleus of Cajal: work with vestibular nuclei and vestibulocerebellum for holding eyes in steady gaze → neural integrator
    - Lesions may cause OTR
- Clinical relevance: **lithium toxicity**

<u>The Cerebellum</u>

- Responsible for trunk control, posture, gait, coordination of movements
- Vestibulocerebellum (flocculonodular lobes, cerebellar vermis)
    - Inferior vermis & flocculonodular lobes regulate balance and eye movements in conjunction with vestibular nuclei
    - Equilibrium and balance
    - Flocculus / paraflocculus: receive visual inputs related to retinal slip, thus help control smooth pursuit eye movements
    - Vermis controls proximal trunk muscles
    - Uvula integrates raw otolithis signals
- Cerebellar hemispheres
    - intermediate are responsible for distal appendicular movements
    - lateral are motor planning for extremities and some cognition
- Clinical relevance: **cerebellar tumors, SCA (spinocerebellar ataxia), MSA (multiple system atrophy); paraneoplastic cerebellar disorders or cerebellar encephalitis → opsoclonus or ocular flutter**

<u>The Thalamus, Basal Ganglia, and Cerebrum</u>

- Thalamus: relay center for the brain; lesions here may mimic a substantial number of syndromes including interstitial nucleus of Cajal
- Basal ganglia: caudate nucleus, putamen, globus pallidus → control/regulation of a variety of functions including control of voluntary motor movements, procedural learning, habit formation, cognition, emotion, and eye movements
    - Inhibition of superior colliculus (controls eye movements based on a retinotopic map)
- Clinical relevance: **Parkinson's, PSP (progressive supranuclear palsy) → postural instability or a diminished ability to make reflex postural adjustments to maintain balance**
- Vestibular cortex: temporo-perisylvian → integrates vestibular information for higher order understanding of location in space
- Parietal cortex: motion perception
- Clinical relevance: **seizures, vestibular migraine, concussion**