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
  o Cilia bend leading to neuronal activation or inhibition
  o Detect angular acceleration
• Otolithic organs → utricle and saccule: curved like ellipsoids to detect 3 dimensions
  o Maculae hair cells embedded in gelatinous membrane with otoconia on top
  o 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
  o Superior transmits anterior and lateral SCC & utricle
    ▪ Runs with facial nerve
  o Inferior transmits posterior SCC & saccule
    ▪ Runs with cochlear nerve
  o Enters brainstem b/w inferior cerebellar peduncle and spinal trigeminal
  o Synapses on vestibular nuclei
• Clinical relevance:
  o Vestibular neuritis → Ewald’s second law: excitation better stimulus than inhibition
  o Viral infections tend to affect superior division w/ facial nerve
  o Meningitis (a disease of meninges in subarach space) commonly affects CN8 first
  o Bilateral vestibular loss: such as from gentamicin, poor signal on both sides (oscillopsia, unsteadiness)

The Vestibular Nuclei & Brainstem

• Brainstem: midbrain, pons, medulla
  o Midbrain connections: thalamus and remaining cortex superior
  o 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

The Cerebellum

- 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

The Thalamus, Basal Ganglia, and Cerebrum

- 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