Applied anatomy of balance system

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Organum vestibulocochleare (acoustic and vestibular organ)

- complex sense organ, in a wider sense, its quintessence is the *labyrinth*
- stems from the flow sensing organ of primitive aquatic vertebrates
- one part of it, completed with other neural organs, develops into the »*vestibular end organ*
- the other part forms the »*acoustic end organ*
Parts of the ear and the cochleovestibular system

- external ear
  - auricle
  - external meatus
- middle ear
  - tympanic membrane
  - middle ear cavity with mastoid cells
  - Eustachian tube
  - ossicular chain
- inner ear
  - bony labyrinth
  - membranous labyrinth
  - ganglia of VIII. cranial nerve

- connection with central nervous system
Bony labyrinth / labyrinthine capsule

*labyrinthus osseus*

- vestibule  
  - *vestibulum*

- bony semicircular canals  
  - *canales semicirculares ossei*

- cochlea  
  - *cochlea*

**Vestibular End Organ**

**Acoustic End Organ**
Vestibule *vestibulum*

- bony cavity seems to be a pear
- connection with middle ear cavity:
  - *fenestra vesztibuli* /oval window
    closed by stapes floatplate and ligaments
  - *fenestra rotunda* /round window
- on the wall cribroform part:
  *macula cribrosa*
- entrance of 3 nerves:
  *n.utriculoampullaris*
  *n.saccularis*
  *n.ampullaris posterior*
Bony semicircular canals

**canales semicirculares ossei**

- 3 semicircular canals in 3 dimensions
- approximately horizontal
  **canales semicirc.lateralis**
- perpendicular to the temporal bone:
  **canales semicirc.anterior**
- in line with temporal bone:
  **canales semicirc.posterior**
- 5 ducts arise from the vestibule
  1 crus osseum simplex
  3 crus osseum ampullare
  1 crus osseum commune
  (anterior and posterior)
- seems to be a cone
- basis: *basis cochleae*
- apex: *cupula cochleae*
- axis is nearly horizontal: *modiulus /blood vessels and n.cochlearis/
- 2 and 3/4 convolutions: *canalis spiralis cochleae, lamina spiralis ossea (membrana basilaris)*
- perilymph: *scala vestibuli, scala tympani*
- in the apex: *helicotrema*
- endolympnph: *ductus cochlearis*
Membranous labyrinth

*labyrinthus membranaceus*

- utricle: *utriculus*
- saccule: *sacculus*
- membranous semicircular canals: *ductus semicirculares*
- cochlear duct: *ductus cochlearis*
Utricle

utriculus

- like a longish bubble, fixed by ligaments
- 6 membranous ducts arise:
  - 3 membranous semicircular canals > anterior and posterior with common duct
  - ductus utriculosaccularis » into the ductus endolymphaticus
- sence end organ: macula utriculi n.utricularis
Saccule
*sacculus*

- round sac, fixed by ligaments
- on medial wall: *macula sacculi*, entrance of *n. saccularis*
- connection to the cochlear duct: *ductus reuniens*
- on the other side: *ductus endolymphaticus*, together with: *ductus utriculosaccularis*
- running and ending in the dura mater *saccus endolymphaticus*
Membranous semicircular canals
*ductus semicirculares*

- it runs along the convex walls of bony semicircular canals
- fixed by ligaments
- open into utricle:
  - common *crus simplex (ant. and post.)*
  - *ampulla membranacea ant. and post.*
  - *ampulla membranacea lateralis*
  - *crus simplex lateralis*
- *ampulla membranacea anterior* and *lateralis near one another*
- in the ampulla - neuroepithelium: *crista ampullaris and cupula*
Cochlear duct
*ductus cochlearis*

- the cochlear duct is an endolymph filled membraneous tube that ends blindly at both ends
- basis: *cecum vestibulare*  
  ( *ductus reuniens* )
- apex: *cecum cupulare*
- borders:
  - *lamina spiralis ossea,*  
    *lamina basilaris* (Corti organ)
  - *paries vestibularis* (Reissner m.)
  - lateral wall, *stria vascularis*  
    *endolymph* production
Tissue structure of vestibular neural end organ

- epithelial thickening:
  - neuroepithel cell (hair cell)
  - pillar cell
  - stereocilia
  - kinocilium
- distal process of bipolar sensory nerve
- efferent inhibitory nerve
- otholit membrane (gelatinous)
Tissue structure of macula
(utricle, saccule)

- flowerbed-like epithelial thickening
- Stereocilia
- On one edge of the epithelial (hair) cell
  9+2 tubules (regular inner structure)
  > kinocilium
- in the otholitic membrane:
  otoconia (otolits, calcium carbonate cristals)
Tissue structure of crista (canales semicirculares)

- semilunar prominence of the membrane in the *ampulla*, located on the convex side of the semicircular canal
- *cupula* - gelatinous cap that is located on the *crista* and reaches the opposite side
- *kinocilia*, one for each side, are oriented in the similar direction: i.e.
  > towards the semicircular canal in the *anterior and posterior ampullar crista*
  > towards the utricle in the *lateral ampullar crista*
Running of the VIII. cranial nerve

- **exit from brain:** pons-arms of pons, run together:
  - n. facialis
  - n. cochleovestibularis
  - n. intermedius (sensory and praeganglionanr vegetative part of facial nerve)
- **exit from dura mater:** across porus acusticus internus > into meatus acusticus internus (approx. 1 cm long)
- **in the meatus acusticus internus**
  - superior-posterior part: *pars vestibularis, ganglion vestibulare* (Scarpaes)
  - anterior-inferior part: *pars cochlearis, ganglion spirale*
• the bottom of the internal auditory canal is divided by the bony crest into four unequal parts
  sup.,ant.,medial: *area facialis*
  sup.,post.,lateral: *area vestibularis superior*
    - *n.utriculoampullaris* - *n.utricularis*
    - *n.amp.anterior*
    - *n.amp.lateralis*
  inf.,post.,lateral: *area vestibularis inferior*
    - *n.saccularis*
  area vestibularis posterior
    - *n.amp.posterior*
  inf.,ant.,medial: *area cochlearis* - *n.cochlearis*
• The two posterior quadrants are the *part of maculae cribrosa*
Branches of vestibular nerve

SVN: superior vest. nerve
IVN: inferior vest. nerve

SA: amp. sup.
HA: amp. horisont.
PA: amp. post.

UM: macula utriculi
SM: macula sacculi
Nuclei vestibulares

- in the deep part of the IV. ventricle in the medulla oblongata
- it consists of cells of bipolar neurons, coming from receptors
- first processing of vestibular informations
- from these vestibular nuclei arise pathways to different nervous system structures

- *nucleus medialis* (Schwalbe)
- *nucleus superior* (Bechterew)
- *nucleus lateralis* (Deiters)
- *nucleus descendens spinalis* (Roller)
Vestibular pathways

- From vestibular nuclei arise some complex pathways:
  - vestibuloocular (fasciculus longitudinalis medialis)
  - vestibulocerebellar
  - vestibulospinal (motoneurons)
  - to the formatio reticularis
  - to the archicerebellum (flocculo-nodular lobe)
  - extrapyramidium
  - autonomic nervous system (nucl. of n. vagus)
  - temporal lobe
- The vestibular and cochlear representation of the cortex are nearly around.
Cochlear pathway

afferent pathway:

nucleus cochlearis (the first connection of bipolar cells of the ganglion spirale in the medulla oblongata, bilateral representation)

- oliva superior
- lemniscus lateralis
- colliculus inferior (middle brain)
- corpus geniculatum mediale (thalamus)
- gyrus temporalis superior, fissura Sylvii (auditory cortex)

efferent pathway

- from oliva superior (regulation of motility of outer hair cells)
Functioning of the vestibular apparatus

- Bending of stereocilia and kinocilia towards a certain direction: depolarisation, towards the opposite direction: hyperpolarisation.
- Baseline situation: a series of action potentials are generated at a baseline frequency in the vestibular nerve.
- Frequency of the electrical impulses travelling towards the central structures are increased by depolarisation and decreased by hyperpolarisation.
Functioning of the macula
(utriculus, sacculus)

- detects *linear acceleration*
- calcium carbonate crystals bend the hairs in macula, according to the direction of *linear acceleration* and *gravity*
- extent of bending is detected by the otolithic apparatus
- **examination method:** positional nystagmus test
Functioning of the crista

*(semicircular canals)*

- detects *angular acceleration*
- operation principle of semicirc. canals is based on the inertia of fluids
- when turning the head in the plane of the semicircular canal, the fluid inside lags behind compared to the body > the *cupula bends*
- bending of the cupula is detected as *angular acceleration* by the nervous system
- if stereocilia are bent towards the kinocilium, the impulse rate increases, and vice versa
- in the lateral semicircular canals, endolymph flow towards the ampulla (ampullopetal) elevates the impulse rate, while an opposite flow (ampullofugal) creates a lower impulse
- in the two other semicircular canals the situation is just the opposite
- examination method: positioning nystagmus, caloric reaction, post-rotational test
• the two labyrinths show antagonist operation, except the sagittal semicircular canals
• the antagonist effect of the two sides maintains a postural equilibrium
• labyrinth excitation symptom of one side can be provoked by the paralysis of the other side
• influence on muscle tone: in case of paralysis of one labyrinth (along with the maximum excitation of the other side) muscle tone shows a typical deviation, also affecting the coordination of ocular muscles (conjugated deviation)
• tilting, gaiting pointing and slow phase of nystagmus consistently directed towards the paralytic side > harmonic vestibular syndrome
Nystagmus

- **based on:** vestibuloocular reflex, (connection between the vestibular nuclei and oculomotorius nuclei across the fasciculus longitudinalis medialis)
- **function:** stabilisation of the field of vision
- complex eye movement consist of two phases: primary slow beating phase and secondary compensatory fast beating phase
- the direction of the nystagmus is named by the fast beating phase based of historical cause
- **intensity:**
  - grade I: it can be detected only when the eyes gaze towards the fast component
  - grade II: it is also present when the patient looks straight ahead
  - grade III: it is also detected when the eyes gaze towards the slow component
• turning the head into the right side > endolymph is moving into the left side > on the right side excitation > on the left side inhibition >
• imbalance in the central nervous system leaves off >
• creates electrical impulses into the oculomotorius nuclei >
• eyeballs slowly turn to the left side (into the inhibited side) slow component >
• compensation in the brain stem >
• eyeballs return quickly in the middleline > fast component
Blood supply of the ear

- **external ear:** a.carotis externa - a.temporalis superficialis
  - a.auricularis posterior

- **tymp.membr.:** a.carotis ext. - a.maxillaris int. - deep auricular branches (tymp.mbr.lat.part)
  - a.tymp.ant.
    (tymp.mbr.med.part)
  - a.auricularis post. - a.stylomastoidea (tymp.mbr.med.part)

- **middle ear:** a.carotis ext.-a.maxillaris int. ------------------a.tymp.ant.
  - a.mening.med.-a.tymp.sup.
  - a.auricularis post.------------------a.tymp.post.
  - a.pharyngea asc.------------------a.tymp.inf.
  a.carotis int.-----------------------------a.caroticotym.

- **mastoid:** a.carotis int.- a.occipitalis
Blood supply of bony labyrinth


- a. pharyngea ascendens - a. tympan.
a. vertebrobasilaris and its branches
a. vertebrobasilaris

AV: a. vertebralis
AB: a. basilaris
AICA: a. cerebelli inf. anterior
AL: a. labyrinthi
Supply of a. labyrinthi 
(membranous labyrinth)
Thank you for your attention!