met het oog op evenwicht

Herman Kingma,
Department of ORL, Maastricht University Medical Centre
Faculty of Biomedical Technology, Technical University Eindhoven
problems in patients with dizziness and balance disorders

- complex history
  which complaints relate to vestibular deficits?
- standard vestibular tests generally applied
  low sensitivity - low specificity
- vestibular diseases
  pathophysiological mechanisms?
- therapy
  causal versus symptomatic medication: indication area? mode of action?
  ablation: neurectomy / local gentamycine application
  labyrinthine substitution systems - vestibular implants
which complaints are related to vestibular deficits?

limitations of diagnostics?
CNS
interpretation
learning
adaptation
compensation

somatosensory
e.g. foot sole pressure

vision

hearing

circadian rhythm
vestibular projections
hypothalamus
supra-chiasmatic nucleus

autonomic processes
blood pressure regulation
heart beat frequency
respiration rate
nausea / vomiting

labyrinths

image stabilisation

spatial orientation

balance control

gravitoreceptors
blood pressure sensors in large blood vessels

somatosensory
e.g. foot sole pressure

hearing

somatosensory
e.g. foot sole pressure

vision

labyrinths

image stabilisation

spatial orientation

balance control
summarizing: vestibular dysfunction implies acute loss or fluctuating function

**transient:** vertigo, nausea, falling / imbalance

remaining peripheral vestibular function loss

**sustained:**
- persisting episodes of not feeling well
image stabilisation

balance control

circadian rhythm
vestibular projections
hypothalamus
supra-chiasmatic nucleus

spatial orientation

vision

hearing

labyrinths

gravitoreceptors
blood pressure sensors in large blood vessels

autonomic processes
blood pressure regulation
heart beat frequency
respiration rate
nausea / vomiting

CNS
interpretation
learning
adaptation
compensation

somatosensory
e.g. foot sole pressure

vision gravitoreceptors

blood pressure sensors in large blood vessels

somatosensory

e.g. foot sole pressure

vision

hearing

labyrinths

gravitoreceptors

blood pressure sensors in large blood vessels

autonomic processes
blood pressure regulation
heart beat frequency
respiration rate
nausea / vomiting

image stabilisation

spatial orientation

balance control
summarizing: vestibular dysfunction implies
acute loss or fluctuating function

transient: vertigo, nausea, falling / imbalance

remaining peripheral vestibular function loss

sustained:
- persisting episodes of not feeling well
- reduced spatial orientation abilities
vestibular impact upon postural control

- regulation of muscle tone relative to gravity

- regulation of COM relative to base of support balancing correction steps

- labyrinths important for balance at low speed learning motor activities → automatisation
visual cortex

hippocampus spinal pattern generator

vn

cer
otolith function especially relevant for:

motor learning (retardation in congenital areflexia)
maintaining and automatization of complex postures
standing or slow walking
  on a soft surface (wind-surfing)
in darkness
in presence of misleading visual stimuli

labyrinths less relevant for:

walking at normal speed or running (visual anticipation)

bilateral areflexia leads to degeneration of
“head direction” and head “place” cells in the hippocampus
patient with severe bilateral vestibular hyporeflexia

slow tandem walk          fast tandem walk
summarizing: vestibular dysfunction implies

- acute loss or fluctuating function

  transient: vertigo, nausea, falling / imbalance

remaining peripheral vestibular function loss

- sustained:
  - persisting episodes of not feeling well
  - loss of balance at low speeds
  - reduced automatization and spatial orientation
  - reduced multi-tasking
- Image stabilization
- Balance control
- Spatial orientation
- Interpretation
- Learning
- Adaptation
- Compensation
- Vision
- Hearing
- Autonomic processes:
  - Blood pressure regulation
  - Heartbeat frequency
  - Respiration rate
  - Nausea/vomiting
- Gravitoreceptors:
  - Blood pressure sensors in large blood vessels
- Labyrinths
- CNS:
  - Interpretation
  - Learning
  - Adaptation
  - Compensation
- Circadian rhythm:
  - Vestibular projections
  - Hypothalamus
  - Supra-chiasmatic nucleus
- Somatosensory:
  - E.g. foot sole pressure
- Vision gravitoreceptors
- Blood pressure sensors in large blood vessels
- Hearing somatosensory
- E.g. foot sole pressure
- Somatosensory e.g. foot sole pressure
VOR: 8 msec
OKR and Smooth pursuit: >75 msec
head impulse test in unilateral loss
standard video (50 Hz)
head impulse test in bilateral loss
high speed recording (300 Hz)
simulation of oscillopsia $\approx$ reduced dynamic visual acuity in case of bilateral vestibular areflexia
which complaints are related to vestibular deficits?

limitations of diagnostics?
summarizing: vestibular dysfunction implies acute loss or fluctuating function

transient: vertigo, nausea, falling / imbalance

remaining peripheral vestibular function loss

sustained:
- persisting episodes of not feeling well
- loss of balance at low speeds
- persistent reduced dynamic visual acuity
- reduced automatization and spatial orientation
- reduced multi-tasking
- secondary: fear and fatigue
a vestibular function loss implies permanent impairment analogue to hearing and visual losses

examples
- ageing:
  >65 vestibular function loss in 32% (Neuhauser et al.)
- Meniere’s disease when attacks are absent or disappeared
- neuritis vestibularis after central compensation
- bilateral vestibulopathy after central compensation
- vestibular loss schwannoma (also after extirpation)
which complaints are related to vestibular deficits?

limitations of diagnostics?
can we objectify and localize vestibular deficits?
kinocilium
stereocilia
tip links
nerve fibre

A

B

C
myosine filaments

action potentials

ion channels

sensitive

less sensitive

80 mV

60 mV

120 mV
labyrinth
- rotations: canal system
- translations + tilt: statolith systems

semicircular canal
- accelerometer
- inertia of mass
- asymmetrical sensitivity
- frequency dependence
loss of gaze stabilisation (towards bad-side)
especially for fast head movements
cupula deflection depends on frequency head movement
- canal only senses acceleration, no constant velocities
- most diagnostic test at less relevant low frequencies
quantification of Sensory Function

two labyrinths

- horizontal canals only

additional evaluation needed of:

- anterior canals

- posterior canals

- utriculi

- sacculi

not relevant ?
labyrinth
- rotations: canal system
- translations + tilt: statolith systems

utriculus + sacculus
accelerometers
- function based on inertia of statoconia mass
- multi-directional symmetrical sensitivity
- frequency dependence
velocity

constant velocity

acceleration
deceleration

no discrimination between translation and tilt possible
vestibular system senses medium frequency translations and tilts

frequency dependence after central processing

sensitivity

vision + proprioception

statolith system

vestibular system senses medium frequency translations and tilts

frequency (Hz)
localisation of labyrinth dysfunction in detail is now possible, but requires complex equipment
treatment

- treatment often focussed on paroxysms

- treatment, prothesis for vestibular function loss?

  - vestibular implant
  - vibrotactile labyrinthine substitution system
sensor random          sensor on

nieuwslicht 2007
conclusion:

- vestibular function loss is often not adequately objectified
- impact of vestibular function loss is often poorly understood is often underestimated