impact of the loss of vestibular function

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vestibular pathology (traditional view)

- initial symptoms: vertigo, nausea and nystagmus
- central compensation
  - unilateral: the other labyrinth takes over
  - bilateral: sensory substitution takes care
- recovery in a few weeks to months
vestibulopathy

two aspects

• vertigo, nausea and nystagmus

• sensory dysfunction or function loss
**Acute** unilateral loss or fluctuating function (neuritis, Ménière…)

Acute severe vertigo, nausea, falling and imbalance
(the classical leading symptoms for diagnosis)

**Slow** unilateral loss (vestibular schwannoma, aging):

No vertigo or nystagmus

What happens in case of acute **bilateral** loss?
May 2008
Mans Magnusson
Michael Karlberg
Lund, Sweden

Lidocaine 2 mg /ml
Topical prilocaine (EMLA) on eardrums

Intratympanal injection of lidocaine (spinal tap needle)
1. Right side
3. Wait and see
some time later when he wants to get up feeling a bit ....
returning from the toilet after severe vomiting
- duration 8 hours
- reproducible
acute bilateral vestibular loss

no vertigo, no nystagmus

severe unsteadiness / ataxia

intolerance for voluntary head movements

clear neuro-vegetative symptoms
in case of acute asymmetries

- vertigo and nystagmus

slow unilateral, slow or acute bilateral loss

- no vertigo or nystagmus

vertigo is only 1 aspect of vestibular loss
vestibulopathy

aspects that require management:

- vertigo and nystagmus
  (occur in case of acute asymmetries)

- sensory dysfunction or function loss

- nausea
let us focus now on the impact of the sensory deficit per se

what is the major impact of loss of vestibular loss?
Image stabilisation

Gravitoreceptors
- Blood pressure sensors in large blood vessels

Labyrinths

Vision

CNS
- Interpretation
- Learning
- Adaptation
- Compensation

Hearing

Somatosensory
- E.g. Foot sole pressure

Circadian rhythm
- Vestibular projections
- Hypothalamus
- Supra-chiasmatic nucleus

Autonomic processes
- Fast blood pressure regulation
- Heart beat frequency
- Nausea / vomiting

Vestibular effects on cerebral blood flow
Serrador et al, BMC Neuroscience 2009

Vestibular modulation of circadian rhythm
Fuller et al, Neuroscience 2004

Image stabilisation

Spatial orientation

Balance control

Blood pressure regulation

Heart beat frequency

Nausea / vomiting
consequence of slow or acute vestibular sensory loss:
- often persisting neuro-vegetative symptoms
  (nausea, sweating, problems with blood pressure)
CNS interpretation learning adaptation compensation

- gravitoreceptors
  - blood pressure sensors in large blood vessels
- labyrinths
- vision
- hearing
- somatosensory
  - e.g. foot sole pressure
- autonomic processes
  - fast blood pressure regulation
  - heart beat frequency
  - nausea / vomiting
  - Vestibular effects on cerebral blood flow
    - Serrador et al, BMC Neuroscience 2009
- circadian rhythm
  - vestibular projections
    - hypothalamus
    - supra-chiasmatic nucleus
    - Vestibular modulation of circadian rhythm

- image stabilisation
- spatial orientation
- balance control
- vestibular projections to:
  - hypothalamus
  - supra-chiasmatic nucleus

- vestibular effects on:
  - cerebral blood flow
  - circadian rhythm

- Serrador et al, BMC Neuroscience 2009
consequence of slow or acute vestibular sensory loss:
- reduced perception of self motion and spatial orientation
  (frequently intolerance to optokinetic stimuli)
consequence of slow or acute vestibular sensory loss:
- reduced perception of self motion and spatial orientation (frequently intolerance to optokinetic stimuli)

Sylvie Wiener-Vacher, 2013
**CNS**

- interpretation
- learning
- adaptation
- compensation

**Sensory Systems**
- **Gravitoreceptors**
  - Blood pressure sensors in large blood vessels
- **Labyrinths**
- **Vision**
- **Hearing**
- **Somatosensory**
  - E.g. Foot sole pressure
- **Autonomic Processes**
  - Fast blood pressure regulation
  - Heart beat frequency
  - Nausea / vomiting
  - Vestibular effects on cerebral blood flow
  - Serrador et al, BMC Neuroscience 2009
- **Circadian Rhythm**
  - Vestibular projections
  - Hypothalamus
  - Supra-chiasmatic nucleus
  - Vestibular modulation of circadian rhythm

**Balance Control**

**Image Stabilisation**

**Spatial Orientation**

**Compensation**

**Supra-chiasmatic Nucleus**
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 detection of gravity-vector fast vestibulo-spinal corrections to maintain good posture and prevent falling
- Frontal cortex: initiation, dual tasks
- Cerebellum: rhythm and velocity
- Basal: ganglia modulation
- Brainstem: start and stop
- Spinal cord: automatic spinal patterns (running)
- Labyrinth: fast detection and correction of imbalance (VSR)
the labyrinths add SPEED to balance control
otolith function especially relevant in case of:
- motor learning (retardation in congenital areflexia)
- maintaining postures that need fast feedback (VSR)
- when other senses are compromised;
  - soft surface (mud, sand, wind-surfing)
  - in darkness
  - in presence of confusing optokinetic stimuli

acquired bilateral areflexia leads to degeneration of "head direction" and head "place" cells hippocampus
severe bilateral loss
- 5 months after gentamycine intoxication
- intensive physiotherapy / training
consequence of slow or acute vestibular sensory loss:
- often persisting neuro-vegetative symptoms
- reduced perception of self motion
- intolerance for strong optokinetic stimuli
- reduced ability for fast balance correction
  (need for visual anticipation: fear to fall)
Image stabilisation

Balance control

CNS
Interpretation
Learning
Adaptation
Compensation

Somatosensory
E.g. foot sole pressure

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Vestibular modulation of circadian rhythm
head impulse test in left unilateral loss
standard video (50 Hz)
why video registration?
in 50% of the patients: the correction saccades occur during the head movement: overt saccades
pathology: central compensation

the other labyrinth does NOT take over
1\textsuperscript{st} and 2\textsuperscript{nd} law of Ewald

3D asymmetry
simulation of oscillopsia ≈ reduced dynamic visual acuity in case of bilateral vestibular areflexia
Dynamic Visual Acuity (VA) measurement

treadmill: 2, 4 and 6 km/h
decrease of VA during walking

Normalized VA difference

- 0.2
- 0.2
- 0.3

Normal values (maximum VA decrease)

Velocity [km/h]

- 0.2
- 0.2
- 0.3

- 1.0
- 0.8
- 0.6
- 0.4
- 0.2
0.0
0.2
0.4

BV Patients
Healthy Subjects
Agrawal et al, 2013

DVA reduction (logMar)

HC

years old

PC

AC
which complaints are related to vestibular deficits?
What is the permanent impact of loss of the vestibular sense? (for balance, vision and spatial orientation)

**Loss of speed**
- Poor dynamic vision (daily life)
- Fear to fall and falls

**Loss of automatisation**
- Severe cognitive load:
  - Anticipation constantly required to prevent falls
  - Impaired double tasking
  - Fatigue
- Visual dependence: intolerance to optokinetic stimuli
  - No more shopping or parties
a vestibular function loss implies permanent impairment analogue to hearing and visual losses

examples
- 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)
many vestibular syndromes where vertigo is the leading symptom

- Benign Paroxysmal Positioning Vertigo and Nystagmus
- vestibular neuritis or labyrinthitis / peripheral vestibular ischemia
- vestibular TIA or strokes
- vestibular migraine
- Meniere’s disease (MD)
- recurrent vestibulopathy
- benign paroxysmal vertigo of childhood
- vestibular paroxysms
- vestibular epilepsy
- fistula / superior canal dehiscence syndrome (SCDS)
- vertigo due to central vestibular pathology
take home messages

- vertigo occurs only in case of acute asymmetries

- many patients do not report vertigo at all, but report:
  - 😞 poor (dynamic) vision
  - 😞 fear to fall and falls
  - 😞 fatigue

- treatment of vertigo
  - 😞 reduction of symptoms due to acute loss might impair compensation

- treatment of the sensory deficit because:
  - 😞 deficit is permanent
  - 😞 dynamic central compensation is poor
  - 😞 quality of life is severely decreased