latest development in advanced testing the vestibular function

how to explore the vestibular function in detail

Herman Kingma
ENT Department
Maastricht University Medical Centre
The Netherlands
how I do it in 4 steps

key question: how to trace and localise peripheral and central vestibular deficits

1. history: take time, allow patient to talk, listen, ask and conclude
2. bed side examination
   - differential diagnosis
   - probable diagnosis
3. laboratory testing: localise and quantify dysfunction, confirm diagnosis
4. explanation to the patient
treatment plan
counseling
what vestibular tests?

- clinical examination
- standard tests
- advanced test

interpretation?

- impact on patient management?
- pathophysiology
which indication for vestibular examination:

- paroxysmal vertigo, often with nausea and imbalance
- complaints related to vestibular function loss per se
  imbalance, fear to fall, illusion of body tilt
- reduced Dynamic Visual Acuity
- impaired spatial orientation
- illusion of movements that do not occur
- asymmetric perceptive hearing loss
- oculomotor dysfunction (e.g. fixation problems, diplopia)
- delayed motor development in children
- many diagnostic tests were and are introduced
- only very few survive the years and prove to be clinical relevant
update and latest developments in advanced testing

- Stabilometry, dynamic posturography and gait analysis
- Static Subjective Visual Horizontal/Vertical
- Rotatory chair tests
  3D canal function
    - frequency range:
      - sinusoidal (single or multiple): 0 – 0.64 Hz
      - velocity steps > 1 Hz
    - fixation suppression
    - threshold of 3D rotation
- Statotolith function
  - unilateral /bilateral centrifugation (OCR and SVV)
  - Off vertical axis rotation
- Caloric test
- 3D Video Head Impulse tests
- VEMP’s cervical / ocular
- Galvanic induced body sway and nystagmus
- Hexapod: 6 DOF: thresholds for movements and tilt
update and latest developments in advanced testing

stabilometry, dynamic posturography and gait analysis
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
2. Yeux fermés

Longueur : 1,16 cm/s
Surface  : 0,20 cm/s
Ant-Post/Lat : 3,15

Ant/Post : 0,25 cm/s
Latéral  : 0,08 cm/s
Dynamic Posturography

motor coordination and sensory organisation
Motor coordination tests, EMG postural muscles only abnormal in complete vestibular areflexia or neuromuscular disorders
stabilometry - posturography

- stabilometry: too much overlap between healthy subjects and patients with vestibular complaint or pathology
- motor coordination tests: seldom abnormalities in PVL
- sensory organisation tests: poor specificity

- no clear diagnostic value but tests of functionality
- useful for evaluation and documentation of balance training
- but limited predictive value for daily life performance
best clinical practice:
Observe patient with severe bilateral vestibular hyporeflexia
stop walking when talking: predictor of falls

slow tandem walk
needs fast feed back ..... but is not there!
imbalance as corrections are too slow

fast tandem walk
uses visual anticipation and mass inertia
falls in case of unexpected imbalance
update and latest developments in advanced testing

Static Subjective Visual Horizontal/Vertical
subjective visual vertical (SVV):

- measure of spatial orientation
- depends at least on statolith function
SVV normal values: 0 ± 2.5 degs
new app “SVAPP0” for Iphone and Android available 1-10-2013
static SVV and SVH

- transient abnormal in acute peripheral otolith asymmetry
  (shows involvement statolith system)
- can be and sometimes remain abnormal in central lesions
- SVV method can be used for dynamic statolith tests
update and latest developments in advanced testing

Canal tests

- Caloric test: horizontal canals (unilateral stimulus)
- Rotatory chair tests (bilateral stimulus)
  3D canal function
  frequency range:
  sinusoidal (single or multiple): 0 – 0.64 Hz
  velocity steps > 1 Hz
  fixation suppression
  threshold of 3D rotation
- 3D Video Head Impulse tests (bilateral stimulus)
caloric test: unilateral low frequency HC test

4 water irrigations caloric test still golden standard
• rotatory chairs: predominantly low - middle frequency 3D tests
• identification bilateral vestibular hyporeflexia in children
• tests for fixation suppression
• 3D video-recording complex due to failures of pupil detection
frequency dependence canals: gain

sensitivity

0.1 Hz  10 Hz

VS

calorics  chair  head impulses

frequency (Hz)
frequency dependence canals: phase $\approx$ time constant

- $+90^\circ$
- $-90^\circ$

frequency

0.1 Hz  10 Hz

calorics  chair  head impulses
head impulse test in unilateral loss
standard video (50 Hz)
observation of oculomotor and balance function
head impulse - test (video), DVA test (4 km/h)
caloric test - eyes open in the dark / fixation suppression - 4 calibrations, 4 irrigations, 5 minutes interval
rotatory tests - torsion swing test, velocity steps, fixation suppression,
cervical - Vemp thresholds
ocular - Vemp thresholds
subjective visual vertical (bucket test)
thresholds (rotation, translation and tilt)
posturography (many variants)

VHIT: bilateral normal
AS frequency decay asymmetry

Patient Name:
Patient ID: 0011897676
DOB: 31-5-1937
Gender: Male

Report Operator: Herman Kingma
Lateral Impulse Test: 20-8-2012 12:27
Test Operator: Marie Cecile Gerards

Report Date: 28-6-2013
Left Mean: 0.93, σ: 0.06
Right Mean: 1.20, σ: 0.06
VHIT: bilateral loss and ADS frequency decay

ENT Department MUMC+
P.O. Box 5800
6202 AZ
Maastricht, The Netherlands

Patient Name:
Patient ID: 0001700356
DOB: 6-12-1955
Gender: Female

Report Operator: Herman Kingma
Lateral Impulse Test: 13-8-2012 13:16
Test Operator: Marie Cecile Gerards

Report Date: 28-6-2013
Left Mean: 0.48, σ: 0.06
Right Mean: 0.21, σ: 0.07
VHIT: LF bilateral loss

ENT Department MUMC+
P.O. Box 5800
6202 AZ
Maastricht, The Netherlands

Patient Name: 71892203
Patient ID: 22-12-1949
DOB: 22-12-1949
Gender: Female

Report Operator: Marina Ackermans
Report Date: 14-6-2013
Lateral Impulse Test: 13-6-2013 14:35
Test Operator: Marina Ackermans

Left Mean: 0,04, σ: 0,01
Right Mean: 0,07, σ: 0,02
head impulse test: only real HF test but pitfalls

- too low head velocity: false negatives
- poor instruction: false positives
- check for reproducibility
- use High Speed Video (differences between systems !)
- now vertical HIT also possible but difficult: 3D VHIT

VHIT and calorics are complementary tests: HF + LF

- VHIT is a standard test of first choice but ........
- VALIDATION is not finished
  abnormal: no need for caloric test unless ablative therapies
  normal: caloric test obligatory
ageing (>65) frequency dependence canals
presbyo-vertigo

general population

elderly > 65 yo

sensitivity

frequency (Hz)
other application of the rotation chairs: velocity storage deficits (vestibular memory, canal-otolith interaction)

- intolerance for prolonged movements
- intolerance for prolonged optokinetic stimuli
- e.g. mal de debarquement
velocity storage works for the VOR and the subcortical OKN
labyrinth or retina
OKAN

nph + nodulus

nystagmus

still nystagmus
velocity storage

- makes horizontal canals more sensitive for low frequencies
- improves integration between OKN and VOR
- leads to longer post-rotatory sensations in untrained subjects
- can be evaluated via post-rotatory VOR and OKAN
measuring the perceptual impact of a poor VOR

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

-0.21
-0.20
-0.30

normal values

Velocity [km/h]

BV Patients
Healthy Subjects
update and latest developments in advanced testing

statotolith function

linear translation (sleds)
unilateral /bilateral centrifugation (OCR and SVV)
off vertical axis rotation
VEMP’s cervical / ocular
Tests for utriculus and sacculus

- forwards-backwards, up and downs translations
- sideways translations
utricular and saccular function
linear translation: bilateral stimulation

responses very small

sensitivities and gain

frequency (Hz)

sens (deg/s/m/s2)
sens (deg/s/m/s)
gain (%)

sensitivities and gain

frequency (Hz)
eccentric rotation (centrifuge)
centrifugation (eccentric rotation): unilateral evaluation

Fg

Fc

body tilt illusion (SVV)
eccentricity
unilateral centrifugation clarke variant:

400 deg/s

AD  AS

7.2 cm (distance between utriculi)

problem: < ± 2 degs OCR (±11 degs subjective tilt)
small responses < 3º at 400º/s: limited sensitivity

complex technology and limited sensitivity

problem: < ± 2 degs OCR (±11 degs subjective tilt)
simple alternative: virtual unilateral centrifugation

asymmetry: eye torsion and subjective tilt (SVV with smartphone)
other sacculus and utriculus tests

Cervical Vestibular Evoked Myogenic Potential (c-VEMP):

- modulation of neck muscle activity (EMG)
- by stimulation of the sacculus
- (evaluates vestibulo-collic reflex)

Ocular Vestibular Evoked Myogenic Potential (o-VEMP):

- modulation of eye muscle contraction superior oblique and rectus contraction (EMG)
- by stimulation of the utriculus
- (evaluates vestibulo-ocular reflex, but eye movement too small)
vestibular labyrinth senses low frequency motions: movement
cochlear labyrinth senses high frequency motions: sound
other sacculus and utriculus tests

Cervical Vestibular Evoked Myogenic Potential (c-VEMP):

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VEMP response pathway

Sound

- O-Vemp: utriculus?
- C-Vemp: saccule?
- Vestibular nerve

Superior rectus and oblique muscle (o-VEMP)

Sternocleidomastoid muscle (c-VEMP)
c-VEMP

![Graph showing amplitude and latency](image)

- **Amplitude**: n23
- **Latency**: p13

50 uV
VEMP in practice

visual feedback of EMG to keep muscle contraction constant
o-VEMP
healthy subject

Patient after superior vestibular nerve neuritis

normal c-VEMP: saccular

normal o-VEMP: utricular

abnormal o-VEMP: utricular

normal c-VEMP: saccular
recommendations

c-VEMP: use of visual feedback of rectified EMG obligatory

o-VEMP: 10x smaller amplitudes than c-VEMP, upward gaze necessary: easier

only reliable response parameters are VEMP thresholds and latencies
NOT amplitudes: these depend on muscle size, electrode position etc …. 

2 key references: procedures, normative data, clinical application:

Vestibular evoked myogenic potentials: past, present and future
Rosengren, Welgampola and Colebatch (review)

New perspectives on vestibular evoked myogenic potentials.
Rosengren and Kingma (review)
thresholds of perception of:

angular accelerations

linear accelerations and tilts
results in patients with bilateral caloric and VHIT areflexia

- perception of rotation > 7.7 °/s

- perception of translation > 40 cm/s²

- perception of tilt > 6.2 °
full laboratory examination: listed according to priority
(detailed explanation on request)

• caloric test
  - eyes open in the dark / fixation suppression
  - 4 calibrations, 4 irrigations, 5 minutes interval
• head impulse-test (video), DVA test
• cervical-Vemp thresholds / galvanic VEMP
• ocular-Vemp thresholds
• rotatory tests
  - torsion swing test, velocity steps, fixation suppression, OKAN, OVAR
• subjective visual vertical
• rotation thresholds
• translation and tilt thresholds
• centrifugation (with SVV)
• galvanic stimulation (useful for selection of patients for VI?)
• posturography (many variants)
normal test result does not exclude vestibular function loss