evaluation and quantification of vestibular function:

bedside examination and laboratory testing
- knowledge of the oculomotor and central vestibular pathways
- and interpretation of the basic tests
- an update to most (less known) techniques

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diagnostics: why investigate oculomotor function?

- central vestibular pathways coincide with central oculomotor pathways

- vestibular function is mainly evaluated via VOR which only works with normal oculomotor function
standard

- bed-side examination
- stabilometry /posturography
- spontaneous and fixation nystagmus
- evaluation of oculomotor function
- low frequency rotation tests
- fixation suppression test
- caloric test
- vestibular evoked myogenic potentials
- subjective visual vertical (SVV)
- subjective perception of support tilt (SST)
- optokinetic after nystagmus
- subjective body tilt (SBT)
- head roll induced ocular counterrolling (OCR)
- galvanic induced body sway and OCR
- unilateral centrifugation (OCR and SBT)
- off-vertical axis rotation (OVAR)
- rotatory acceleration thresholds
- translatory acceleration thresholds
specific bed-side examination of the vestibular function

without Frenzel's glasses
1. observe patient's gait / posture
2. Romberg + tandem
3. Past pointing
4. gaze and fixation
5. convergence, amblyopia, cover test, skew deviation
6. pursuit
7. saccades

with Frenzel's glasses
8. spontaneous nystagmus
9. fistel / dehiscence tests (Politzer ballon, Valsalva, Barany box)
10. Hallpike + HC-test
11. 3d VOR + OCR
12. head shake nystagmus test

without Frenzel's glasses
13. head impulse test (H/V)
14. fixation suppression test
15. observe patient's gait / posture
standard

- stabilometry / computerized dynamic posturography: function tests / no strong diagnostic value → Romberg / tandem walk / observation of gait and stance
which eye movement recording technique is optimal for the clinical setting?

EOG versus VOG
search coil technique (SCT): golden standard in clinic not accepted, 1000 Hz, 3D, EO + EC
electro-oculography /electro-nystagmography
0-250 Hz, drift, eye-blink + EMG artifacts, 2D, EO+EC

Eyes moving 30° to the right

Eyes moving 15° to the left
miniature infra-red-video-camera

infrared reflecting mirrors

infrared illumination
video-oculography (VOG) / video-nystagmography (VNG)

50 Hz, 3D but limited range, only EO method: centre of pupil detection
VOG (real time systems, tested: ICS, Hortmann, SMI, Balancelab)
- optimal for BPPV
- OD and OS saccades can be analysed correctly with appropriate software
- field of view and pupil detection range are limited
- correct centre of pupil detection fails in substantial number of the patients
  which remains often unnoticed by the technicians
  (“we never have problems…”)

but the quantitative analysis with simultaneous detection of EOG and VOG
in 746 patients comparing 4 different VOG systems shows the problem

• Wierts R, Janssen MJ, Kingma H.
• Jansen SH, Kingma H, Peeters RM, Westra RL.
• Jansen SH, Kingma H, Peeters RM.

EOG (2D quantitative binocular / 2D qualitative monocular)
- robust clinical method for binocular recordings (no frequency limit)
- eo / ec, unlimited field of view, large range of detection H+V
- saccades can only be analysed reliable binocular
- drift and noise can hamper a good detection (training and supervision)
KNO-arts: doe je audiometrie niet standaard op de kermis

neuroloog: meet geen EEG onder de motorkap van je Volvo

KNO-arts en neuroloog:

- doe dus het evenwichtsonderzoek in een speciale ruimte (gescheiden ruimte voor patient (18 °C) en laborant)
- bereidt de patient voor en houdt de patient optimaal alert
- neem de tijd
- meet met ogen open in het volledig duister
- werk als een team: laborant – arts (terugkoppeling+overleg)
standaard ruimte

- laborant + PC
- intercom
- IR-video
- patient
- bed + stoel
- LED TV
- calorisator
extended ruimte

dynamic visual acuity
spatial orientation. 6 DOF

rotatie, OVAR, centrifugatie

translatie, tilt, SVV, SBT
basic rules

- een goede altijd gemotiveerde laborant is cruciaal
- goed evenwichtsonderzoek vergt tijd en geduld
- controleer de apparatuur regelmatig
- afwijkingen bij het onderzoek kunnen Uw diagnose gesteld bij de anamnese bevestigen en objectiveren
- zonder evenwichtsonderzoek kunt U geen uitspraken doen over de functie van het evenwichtssysteem
- normale bevindingen sluiten geen vestibulair pathologie uit
standard
good equipment is one but ....all depends on your vestibular assistent ....and how you use these data to interprete the patient’s history

- spontaneous and fixation nystagmus
- evaluation of oculomotor function
- low frequency rotation tests
- fixation suppression test
- caloric test
- vestibular evoked myogenic potentials
- subjective visual vertical (SVV)
standard

- spontaneous and fixation nystagmus

fixation nystagmus always pathological

sustained spontaneous nystagmus > 5 °/s pathological
eyes open nystagmus

vertical, horizontal symmetric or pendular

always central (acquired or congenital)

1st, 2nd or 3rd degree horizontal

mostly peripheral
sometimes central
impact of visual fixation upon nystagmus

nystagmus increases by visual fixation
- always central
  (acquired or congenital)

nystagmus decreases upon visual fixation
- always peripheral
- evaluation of oculomotor function
  (see syllabus for interpretation)

fixation
gaze
saccades
optokinetic nystagmus
smooth pursuit
- Low frequency rotation tests
  more sensitive than caloric test to show residual function

torsion swing with / without fixation suppression
velocity steps, rotatory thresholds
standard

- caloric test

4 irrigations with water:  \( AD_{44^\circ C} \quad AS_{44^\circ C} \quad AD_{30^\circ C} \quad AS_{30^\circ C} \)

calibration before each irrigation, 5 minutes in between

eyes open in complete darkness

control patients alertness constantly
current standard vestibular tests evaluate less than 20% of the labyrinthine function

4 water irrigations caloric test still golden standard
standard

- vestibular evoked myogenic potentials
“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 for EOG or VOG)
c- VEMP response pathway

Sound → Saccule → inferior vestibular nerve → sternocleidomastoid muscle (c-VEMP)
o-VEMP response pathway

Sound → Utricle → superior vestibular nerve → superior rectus and oblique muscle (o-VEMP)
c-VEMP

[Diagram of an electrographic signal with labeled peaks n23 and p13 and annotations for amplitude and latency.]
- ipsilateral reflex
- VEMP amplitude increases with stimulus intensity
- absent after vestibular neurectomy with preserved hearing
- present in deaf with normal vestibular function
VEMP in practice

visual feedback of EMG to keep muscle contraction constant
<table>
<thead>
<tr>
<th></th>
<th>average ± SD [dB pSPL]</th>
<th>range (95% C.I.) [dB pSPL]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-40 years</td>
<td>105.9 ± 6.1</td>
<td>95 – 115</td>
</tr>
<tr>
<td>40-60 years</td>
<td>110.7 ± 7.3</td>
<td>100 – 125</td>
</tr>
<tr>
<td>60-80 years</td>
<td>114.1 ± 6.4</td>
<td>105 – 125</td>
</tr>
<tr>
<td>Total</td>
<td>110.2 ± 7.3</td>
<td>100 – 120</td>
</tr>
</tbody>
</table>

thresholds:
  age dependent, need correction for air-bone gap
  left-right threshold: maximal 10 dB difference
<table>
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<tr>
<th></th>
<th>average ± SD [ms]</th>
<th>range (95% C.I.) [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>p13</td>
<td>15.8 ± 1.2</td>
<td>13.8 - 18.5</td>
</tr>
<tr>
<td>n23</td>
<td>24.0 ± 1.7</td>
<td>20.6 - 27.4</td>
</tr>
</tbody>
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latencies: not age dependent
recommendations

- o-VEMP tests: upward gaze necessary, very small signals
- c-VEMP: use of visual feedback of rectified EMG obligatory
- only reliable response parameters are VEMP thresholds and latencies

normal value threshold c-VEMP: 95 – 120 dB peak SPL
latency c-VEMP: 13.8 – 18.5 msec

clinical relevance: SDS, Tullio, extend areflexia
question: saccular
limitation: conductive hearing losses
subjective visual vertical (SVV):

- measure of spatial orientation
- depends at least on statolith function
SVV normal values: 0 ± 2.5 degs
abnormal: acute PVL or brainstem lesions

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- subjective visual vertical (SVV)
head impulse (healthy)

latency = 6 msec
- subjective perception of support tilt (SST)

SST normal values: 0 ± 1.2 degs
abnormal: acute PVL, brainstem lesions, somatosensory
OKAN normal values: < 10 sec
abnormal:
  dysfunction velocity storage
    - acute PVL
    - visual vertigo
    - after long period of immobilisation
    - mal de debarquement

- optokinetic after nystagmus

extended
- subjective body tilt (SBT)

SBT normal values: 0 ± 6 degs

abnormal: acute PVL, somatosensory or brainstem lesions
Ocular Counter Rolling (OCR)

- Static otolith stimulation
- Dynamic vertical canal stimulation

Head roll $40^\circ$
- head roll induced ocular counterrolling (OCR)

OCR > 4.5 degs: functieverlies statolietensysteem
extended

- galvanic induced body sway and OCR
eccentric rotation (centrifuge)

F_c

tilt

ocr

F_g
unilateral centrifugation clarke variant:

$±2$ degs OCR ($±11$ degs subjective tilt)

$400$ deg/s

$7.2$ cm (distance between utriculi)

problem: $< ±2$ degs OCR ($±11$ degs subjective tilt)
extended

- unilateral centrifugation (OCR and SBT)

normal values OCR (0.7G) > 4 degs
SBT thresholds: in development
- off-vertical axis rotation (OVAR)

OVAR normal values: bias < 3 degs
extended

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Conclusion:

- evaluation of vestibular function in detail is possible but
- time consuming
- limited sensitivity and high costs
normal test result does not exclude vestibular function loss