ELECTRONYSTAGMOGRAPHY (ENG)

DEFINTION

- Electronystagmography (ENG) is a diagnostic test to record involuntary movements of the eye caused by a condition known as nystagmus. It can also be used to diagnose the cause of tinnitus, vertigo, dizziness or balance dysfunction by testing the vestibular system.
- Nystagmus may be defined as involuntary movements of eyeballs, either horizontal, vertical or rotatory consisting of slow movement towards one side and a quick return movements towards midline. Direction of nystagmus is designated by the direction of its quick component or fast phase.
- ENG measurements based on the presence of the corneoretinal potential (cornea being positive and retina negative)

PARTS

- Essentially, the standard ENG test battery consists of the following 3 parts:
  - Oculomotor evaluation
    - Saccade (Calibration)
    - Gaze
    - Fixation
    - Tracking (Pursuit)
    - Optokinetic
  - Positioning/positional testing
  - Caloric stimulation of the vestibular system
- Although ENG testing cannot be used to determine the specific site of lesion, the information acquired can be integrated with history, symptoms, and other test results to aid in diagnosis.

PRE-PROCEDURE PLANNING

- Outer and middle ear status should be confirmed prior to caloric assessment. Discharge may affect the results obtained with air caloric stimulation Pressure equalization tubes or perforation of the tympanic membrane precludes the use of water irrigation. Large perforations affect air stimulation also. Cerumen must be removed.
- Many medications can affect test results.
- With physician approval, patients should discontinue all medications, unless contraindicated, for 24-72 hours prior to testing.
- Any medications taken should be clearly noted on the test results.
- Alcohol consumption can affect ENG test results for 72 hours after ingestion; results are unpredictable because alcohol can be an agonist or antagonist.

PATIENT PREPARATION

- If the patient has back or neck injuries, consider positional testing (head hanging) and the Dix-Hallpike maneuver to avoid further complications.
The clinician may want to screen for **vertebrobasilar insufficiency** prior to any positional or positioning test that may constrict the vertebrobasilar artery (i.e., head-hanging or Dix-Hallpike maneuvers). This may include having the patient engage in mental tasking (e.g., counting, reciting multiplication tables) while gradually tilting the head back and then holding. Change in cognitive status or reports of lightheadedness may be significant. This screening method is especially important for older patients.

**TECHNIQUE**

**OCULOMOTOR EVALUATION**

- Only oculomotor function cannot be tested without adequate eye sight.

**SACCADES (CALIBRATION) TEST**

- This system is responsible for rapid eye movements and refixation of the target on the fovea.
- For saccadic testing, one may place dots on the wall or ceiling at specified distances from each other (usually center and 10, 20, and 30 degrees off center) and then instruct the patient to look back and forth between the dots, keeping the head fixed.
- Current technology allows the examiner to control (via computer) the presentation of pinpoints of light on a light bar, on a projection screen, or in an oculomotor stimulator.
- With computer-generated stimuli and analysis, the clinician can assess **latency and velocity** of eye movements.

**INTERPRETATION**

- Normal or basal ganglia pathology
- Hypometric – undershoots
CNS pathology

- Ocular flutter - spiky overshoot

Cerebellum

- Hypermetric overshoot then a correction.
- Multistep saccades undershoots then multiple saccades
- Postsaccadic drift (Glissade) eye drifting after saccade.

PICA

- Pulsion: pulling to left or right after vertical saccades.
- LATENCY – Prolongations of > 400 ms in attentive and cooperative patients may be suggestive of CNS pathology. Asymmetrical latencies can occur in patients with lesions in the occipital or parietal cortex.

GAZE TESTING

- For gaze testing, the patient is instructed to look straight ahead and then fixate on a target 30 degrees to the right, left, up, and down. Fixation is maintained for approximately 30 seconds in center gaze and 10 seconds in eccentric gaze.
- Spontaneous nystagmus i.e. nystagmus in the absence of stimulation
  1. Presence or absence of spontaneous nystagmus
  2. Presence, absence, or exacerbation of nystagmus with addition of off-center gaze
  3. Fixation suppression of spontaneous nystagmus
- Normal gaze position – patient is able to maintain position with eyes open and closed

PERIPHERAL INDICATORS

- Horizontal or horizontal rotary
- Suppressed by visual fixation
- Nondirection changing
- Exacerbated by gazing in the direction of the fast phase*
- Increased on eye closure

CENTRAL INDICATORS

- Vertical
  - Not suppressed by fixation
  - Reduced by eye closure
  - Direction changing
- SO
  - Nystagmus present with eyes open and enhanced by eye closure – lesion is peripheral
  - Nystagmus is enhanced with ocular fixation and reduced by eye closure – lesion is central
By Alexander's law, nystagmus evident with visual fixation always beats in the same direction and increases when the patient gazes in the direction of the fast phase. Nystagmus decreases or disappears when the patient gazes in the direction opposite to the fast phase. This pattern is often seen in peripheral vestibular disorders.

**UNILATERAL GAZE-PARETIC NYSTAGMUS**

- Nystagmus only occurs with eccentric gaze in one direction.
- Elicited nystagmus beats in the direction of the gaze.
- Consistent with CNS pathology

**BILATERAL GAZE-PARETIC NYSTAGMUS**

- Right gaze ➔ right-beating nystagmus
- Left gaze ➔ left-beating nystagmus
- Suggests CNS pathology

**BRUNS NYSTAGMUS**

Combination of

- Unilateral gaze-paretic nystagmus
- Vestibular nystagmus
- Asymmetrical nystagmus in both directions of a gaze
- Associated with extra-axial mass lesions on the side of the gaze-paretic nystagmus

**FIXATION**

- Congenital nystagmus
- Gaze-Evoked Nystagmus
- Rebound nystagmus
- Square-wave jerks

**CONGENITAL NYSTAGMUS**

- Spiky appearance
- Increases with lateral gaze.
- Decrease in velocity or completely disappear with eyes closed

**GAZE-EVOKED NYSTAGMUS**

- Drift of the eye which is only present for certain directions of gaze
- EOG recordings, any persistent nystagmus for ocular displacements < 30 degrees is abnormal
- Causes of Gaze-evoked nystagmus
  1. Medication
  2. Brainstem or cerebellar disorder
  3. Normal variant
  4. Ocular muscle fatigue
5. Congenital nystagmus

**REBOUND NYSTAGMUS**
- Burst of nystagmus
- Begins when the eyes are returned to center gaze.
- Lasting 5 seconds
- Brainstem or cerebellar lesions

**SQUARE-WAVE JERKS**
- The most common abnormality with eyes closed.
- Healthy patients
- Increasing frequency with increasing age.
- Abnormal if
  1. In young patients
  2. More frequently than 1 per second
  3. Eyes open or with visual fixation
- Suggestive of a cerebellar disorder

**SMOOTH PURSUIT TRACKING**
- Follow a sinusoidal moving target with eyes only. eg PENDULUM TRACKING TEST
- Tracking targets within the visual field
- As a rule, vertical tracking is not as smooth as horizontal, even in healthy subjects
- Interpreting with care in geriatric and pediatric
- Affected by attention and patient cooperation.
- Interpretation
- Results should resemble a smooth sinusoid.
- Breakup of movement indicates CNS pathology.

**OPTOKINETIC**
- For optokinetic testing, the patient tracks multiple stimuli.
- These may take the form of stripes on a rotating drum or a stream of lighted dots across a light bar or the field of an oculomotor stimulator.
- Some recent devices allow more natural stimulation, such as a full-field array of moving stars or trees.
- Stimuli are moved at a rate of 300, 400, or 600 per second in each direction.
- Some clinics use both slow and fast speeds; others test at one intermediate speed only.
- Eye movements that are generated by moving fields resemble nystagmus.
- The clinician primarily evaluates symmetry of the response. If responses are not symmetrical, CNS pathology may be suspected.

**POSITIONING**

**DIX-HALLPIKE MANEUVER**
The Dix-Hallpike maneuver is conducted specifically to assess the presence or absence of nystagmus associated with BPPV.

Because one of the typical signs of BPPV is fatigability, the Dix-Hallpike maneuver should be completed before any other positional testing.

Patients with posterior canal BPPV present with a geotropic rotary nystagmus. Because the rotary component is not acquired with traditional electrode systems, the clinician must use infrared technology or Frenzel lenses to observe the direction of rotation.

Response can be suppressed with visual fixation. Keeping the eyes open in a room with enough light for the examiner to observe eye movements may not allow accurate representation of the response.

If rotary nystagmus is observed, the results must have the following 4 characteristics to be considered classically positive:
1. Delayed onset, in which nystagmus begins a few seconds after the patient is positioned (so observe 20 seconds)
2. Transient burst of nystagmus, in which nystagmus lasts less than a minute
3. Subjective report of vertigo
4. Fatigability, in which the response decreases with repetition

In addition to these 4 characteristics, the clinician may observe a reversal of the nystagmus. When the patient resumes the sitting position, the nystagmus may begin beating in the opposite direction.

When a classically positive response is observed during the Dix-Hallpike maneuver, a peripheral lesion on the side that is down when the nystagmus occurs may be indicated.

**POSITIONAL TESTS**

The examiner places the patient in each position and evaluates him or her for a minimum of 20-30 seconds.

Mental tasking is used to keep the patient from suppressing nystagmus. Visual suppression must also be avoided by the use of infrared goggles or with the patient’s eyes closed with electrodes.

Some standard positions used include the following:
- Head hanging
- Supine
- Supine, head right
- Supine, head left
- Lateral right
- Lateral left

Many clinics do not assess in the lateral right and left positions unless nystagmus is observed in the supine position with the head to the right or left.

The lateral right and left positions are used to rule out neck rotation as a cause for nystagmus.

Nonstandard positions include any position in which the patient reports dizziness (eg, dizziness when bending to tie shoes).

If no nystagmus is observed in any position, results are considered normal.

For results to be considered abnormal
- The nystagmus observed in positional testing should exceed 6 degrees per second
- Change direction in any 1 position
- Persist in at least 3 different positions
- Be intermittent in all positions.
Lesser degrees of nystagmus are of questionable pathologic significance.  
Peripheral indicators include the following:
- Direction-fixed
- Geotropic direction changing in different positions, (horizontal SCC variant of BPPV)
- Latency of onset
- Fatigable
Central indicators include the following:
- Ageotropic direction changing in different positions,
- Direction changing in a single position,
- Immediate onset
- Not fatigable

**CALORIC STIMULATION**

Caloric stimulation of the vestibular system offers an assessment of the lateral semicircular canal.

- The most informative ENG subtest  
- Water, air, and closed-loop cuff  
- Water calorics provide a strong stimulus  
- Air, and closed-loop cuff used with PET or perforation of TM  
- Cool = 30 C warm = 44 C  
- Response pattern follows the form of COWS  

**Alternating Binaural Bithermal Caloric Stimulation**

- Alternating binaural bithermal caloric stimulation, which is probably the most commonly used protocol for caloric stimulation, includes the following conditions:
  - Right ear cool (RC)  
  - Left ear cool (LC)  
  - Left ear warm (LW)  
  - Right ear warm (RW)  
  - Give for preset time, engage in Mental Task, after stimulus removed recording continued while patient is mentally tasked.  
  - The patient is given a break of 3-5 minutes between the RC and LC calorics and between the LW and RW. A break of 8-10 minutes is given between the LC and LW conditions.  

**Monothermal Caloric Irrigations**

- Only warm stimulation  
- If the responses from each ear are equivalent and robust, testing is terminated.  
- If a difference in responses exists between the 2 ears or the responses are less than 20 degrees per second, bithermal caloric testing is conducted.

**INTERPRETATION**

**Caloric stimulation**

- Unilateral weakness (UW) Labrynthine preponderance (LP)
evaluate symmetry
- > 25% is significant.
- \[= \frac{(RC + RW - LC + LW)}{(RC + RW + LC + LW)} \times 100.\]
- peripheral lesion (nerve or end-organ)
- lesion in the side of the weakness.

**Directional preponderance (DP)**
- with spontaneous nystagmus
- >20-30% is considered significant.

**Bilateral weakness**
- Average responses of <60/s
- bilateral peripheral or central
- drug effects should be excluded

**FIXATION SUPPRESSION**
- After each caloric stimulus, the patient is instructed to fixate on a light or other stationary target. Fixation should normally eliminate or greatly reduce the induced nystagmus. If visual fixation does not inhibit nystagmus, central pathology at the level of the brain stem is indicated. The clinician must ensure that fixation suppression testing is completed as soon as the peak nystagmus response has been recorded. Fixation suppression testing is not accurate if the clinician waits to introduce the stimulus until the response has naturally decayed.

**SPECIAL APPLICATIONS**

**PRESSURE FISTULA TEST**
- Some patients have vertigo caused by a perilymph fistula. Fistula testing can be conducted with ENG to determine which patients are likely to benefit from perilymph fistula repair surgery
- upright position
- Patient is involved in mental tasks, recordings are conducted with the patient’s eyes open in the dark (wearing infrared goggles) or with eyes closed with electrodes.
- The presence or absence of spontaneous nystagmus is noted
- Next, a probe from an immittance bridge is placed in the ear canal and a seal is obtained.
- Pressure is then varied from 0-200 mm H2 O and held for approximately 15 seconds.
- Pressure is then decreased to -400 mm H2 O and held for 15 seconds.
- The patient is questioned for subjective symptoms.
- The presence of a fistula is confirmed if the pressure causes nystagmus.

**TULLIO PHENOMENON**
- This is not as routinely used as pressure fistula testing, but the Tullio phenomenon is an option for patients on whom a hermetic seal cannot be obtained.
Follow the procedure for a pressure fistula test, but instead of varying the air pressure, present a 500-Hz tone at 95 dB for no longer than 3 seconds. Monitor eye movements and ask the patient about his or her subjective experience.

**HEAD-SHAKE NYSTAGMUS TEST**

- The head-shake nystagmus test is most useful in the assessment of vestibular disorders that produce asymmetries in vestibular function.
- For this test, the patient is placed in an upright sitting position with his or her head tilted forward 30 degrees.
- The examiner rotates the head back and forth (45 degrees to either side), completing 30 full cycles at a frequency of about 2 cycles per second. If nystagmus is observed following head rotation, eye movements should be recorded for at least 1 minute.
- Nystagmus produced after the head rotation is considered significant if at least 5 consecutive beats of at least 2 degrees per second are observed.
- Head-shake nystagmus is described by the following classifications:
  - **Monophasic**, in which the nystagmus produced does not change directions
  - **Biphasic**, in which the nystagmus produced initially beats in one direction and then fatigues and reverses directions
  - **Paretic**, in which the initial nystagmus observed beats away from the side of lesion
  - **Reversed**, in which the initial nystagmus observed beats toward the side of lesion
  - **Cross-coupled**, in which a strong vertical nystagmus is produced by head shaking on the horizontal axis
- A positive finding of head-shake nystagmus is highly suggestive of an underlying vestibular pathology.
- Cross-coupled head-shake nystagmus is suggestive of CNS pathology.

**VIBRATION-INDUCED NYSTAGMUS**

- Nystagmus may be induced in patients by stimulating the head and/or neck with vibrations. Vibration-induced nystagmus may be useful in the diagnostic confirmation of unilateral lesions.
- Upright sitting position and a vibrator is applied to the mastoid.
- Eye movements are recorded in the dark while a vibratory stimulus of 100 Hz is presented to the mastoid.
- Recordings should be obtained separately for the right and left mastoid.
- Vibratory stimulation may likewise be presented to the sternocleidomastoid muscles to induce vibration-induced nystagmus.
- A positive finding of vibration-induced nystagmus occurs when nystagmus appears during vibratory stimulation and disappears when the stimulation terminates. The nystagmus may have several components but is predominantly horizontal.
- In patients with a unilateral lesion, the vibration-induced nystagmus most often beats in the direction of the nonaffected side. The exception to this is Meniere disease, in which the vibration-induced nystagmus may beat in either direction.