A Flow Chart For Classification Of Nystagmus

Is fixation impaired because of a slow drift, or an intrusive saccade, away from the target?

If a slow drift is the culprit

Jerk

Unidirectional

Vestibular (constant velocity)

Central pure vertical or pure torsion, vergence increases

Peripheral suppressed by fixation, obeys Alexander’s Law, mixed horizontal-torsion

Changes direction with viewing eye, velocity decreasing Latent Nystagmus

Changes direction with direction of gaze (gaze-evoked)

Acquired (velocity decreasing, with rebound nystagmus e.g. cerebellar)

Acquired MS, OPT (with palatal tremor)

Congenital (damped by vergence)

Congenital (velocity increasing, damped with convergence)

Pendular

See-Saw (congenital or acquired, bitemporal vf loss)

Whipple’s (vergence-divergence, jaw movement)
Waveforms of Nystagmus

A: Jerk or linear (vestibular)

B: Velocity-decreasing (acquired gaze-evoked, latent)

C: Velocity-increasing (usually congenital)

D: Pendular
SCC Organization: a guide to nystagmus

Arrows indicate direction of slow phase with stimulation

Central Patterns

Peripheral Pattern

Eyes (head) rotates in a plane parallel to that of the rotation of the head and so stabilizes gaze (eye in space) around all three axes of head rotation

Flourens
A Flow Chart For Classification Of Nystagmus

Is fixation impaired because of a *slow drift*, or an *intrusive saccade*, away from the target?

If a *saccade* is the culprit?

With an intersaccadic interval (150-200 ms) before the return saccade

- **Square-wave jerks** (small saccades away from and back to fixation, e.g., PSP, cerebellar disease)
- **Macrosaccadic oscillations**, Large saccades around fixation (extreme degree of saccade hypermetria)

Without an intersaccadic interval (back to back saccades)

- **Opsoclonus** (multiaxis); worse with eye closure, vergence
- **Flutter** (one axis)
  - Includes ‘voluntary nystagmus’
  - Worse with eye closure, vergence

With an intersaccadic interval (150-200 ms) before the return saccade

- **Macrosquare wave jerks** (much larger saccades)
- **Convergence-retraction** (Pretectal syndrome)

Without an intersaccadic interval (back to back saccades)

- **Ocular Bobbing**
  - Down saccade and slow drift back up (dipping, reverse, inverse, converse)
- **?Spasmus Nutans**
Ocular Bobbing

- Saccade
- Slow Drift

Bobbing

- Reverse dipping (converse bobbing)

Dipping (inverse bobbing)

Reverse bobbing
<table>
<thead>
<tr>
<th>Nystagmus type</th>
<th>Treatment (dose, frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infantile nystagmus</td>
<td>Gabapentin (300–600 mg, qid)</td>
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<tr>
<td></td>
<td>Memantine (10 mg, qid)</td>
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<tr>
<td></td>
<td>Acetazolamide (250–1000 mg, bid)</td>
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<td>Brinzolamide 1% eye drops (1 drop, bid)</td>
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<td>Downbeat nystagmus</td>
<td>4-aminopyridine (5–10 mg, tid; 10 mg ER bid)</td>
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<td></td>
<td>3,4-diaminopyridine (10–20 mg, tid)</td>
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<td></td>
<td>Clonazepam (0.5–1 mg, bid)</td>
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<td>Upbeat nystagmus</td>
<td>Memantine (10 mg, qid)</td>
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<tr>
<td></td>
<td>4-aminopyridine (5–10 mg, tid; 10 mg ER bid)</td>
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<tr>
<td></td>
<td>Baclofen (5–10 mg, tid)</td>
</tr>
<tr>
<td>Torsional nystagmus</td>
<td>Gabapentin (300 mg, qid)</td>
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<tr>
<td>Periodic alternating nystagmus</td>
<td>Baclofen (5–10 mg, tid)</td>
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<td></td>
<td>Memantine (5–10 mg, qid)</td>
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<tr>
<td>Acquired pendular nystagmus in MS</td>
<td>Gabapentin (300 mg, qid)</td>
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<tr>
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<td>Memantine (10 mg, qid)</td>
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<td>Acquired pendular nystagmus in OPT</td>
<td>Gabapentin (300 mg, qid)</td>
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<td>Memantine (10 mg, qid)</td>
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<tr>
<td></td>
<td>Trihexyphenidyl (5–20 mg, tid)</td>
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<tr>
<td>Episodic ataxia (type 2)</td>
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<td></td>
<td>4-aminopyridine (5–10 mg, tid; 10 mg ER bid)</td>
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<tr>
<td>Seesaw nystagmus</td>
<td>Alcohol</td>
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<tr>
<td></td>
<td>Clonazepam (0.5–1 mg, bid)</td>
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<tr>
<td></td>
<td>Memantine (10 mg, qid)</td>
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</tbody>
</table>

Thurtell Leigh, Current treatment Options, 2011
<table>
<thead>
<tr>
<th></th>
<th>Direction of nystagmus (quick phase)</th>
<th>Waveform (slow phase)</th>
<th>Special features</th>
<th>Sites of lesion</th>
<th>Etiology</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>downward, may be diagonal with lateral gaze</td>
<td>jerk, constant, increasing, or decreasing slow-phase velocity</td>
<td>increased intensity during lateral and downward gaze; sometimes suppressed by convergence</td>
<td>cerebellum (bilateral floccular hypofunction); rarely lower brainstem lesions</td>
<td>cerebellar tumors, degenerations, and stroke; idiopathic; often associated with bilateral vestibulopathy and neuropathy</td>
<td>4-aminopyridine (5-10 mg tid), 3,4-diaminopyridine (10-20 mg tid), baclofen (5 mg tid), clonazepam (0.5 mg tid)</td>
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<tr>
<td></td>
<td>upward</td>
<td>jerk, constant, increasing, or decreasing slow-phase velocity</td>
<td>increased intensity during upward gaze; may convert to DBN on convergence</td>
<td>medial medulla, pontomesencephalic junction, rarely cerebellum</td>
<td>brainstem or cerebellar stroke and tumors; Wernicke's encephalopathy</td>
<td>often transient, treatment often not necessary; baclofen (5-10 mg tid) 4-aminopyridine (5-10 tid)</td>
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<tr>
<td></td>
<td>mainly horizontal, may have vertical and/or torsional components</td>
<td>pendular, sinusoidal slow-phase</td>
<td>associated with other oscillations (e.g., palate) and with hypertrophic degeneration of the inferior olive</td>
<td>pontomedullary, probably affecting components of neural integrator for gaze holding</td>
<td>multiple sclerosis, oculopalatal tremor due to brainstem or cerebellar stroke</td>
<td>memantine (10 mg qid) gabapentin (300 mg qid)</td>
</tr>
<tr>
<td></td>
<td>horizontal</td>
<td>Jerk, mostly constant slow-phase velocity</td>
<td>changes direction every 90 to 120 sec</td>
<td>cerebellum (nodulus, uvula)</td>
<td>cerebellar degenerations, cranio-cervical anomalies, multiple sclerosis, cerebellar tumors and stroke</td>
<td>baclofen (5-10 mg tid)</td>
</tr>
<tr>
<td></td>
<td>mainly horizontal; may have torsional and small vertical components</td>
<td>accelerating slow-phases; foveation periods when the eye is transiently still</td>
<td>null zone, in which nystagmus is minimal; often suppressed with convergence</td>
<td>uncertain; some cases are associated with afferent visual system anomalies</td>
<td>uncertain; may be associated with afferent visual system anomalies; hereditary in some patients (e.g., FRMD7 mutations)</td>
<td>gabapentin (300 mg qid) memantine (10 mg qid)</td>
</tr>
</tbody>
</table>

**Summary table of nystagmus treatment** (Strupp et al, J Neurology, 2011)
The Brain Stem Pulse Generator: The key classes of neurons

Pause neurons (P) inhibit burst neurons when fixation is required.

Burst neurons (B) generate the pulse for a saccade.

Neural integrator (T) generate the step for a saccade.

Oculomotor neuron pulse-step

Saccade
Brainstem control of horizontal gaze (leftward)

Convergence -- direct input to III nucleus

PPRF* EBN (excitatory burst neurons)

VI nucleus

NI (Neural Integrator (MVN and N. prepositus))

PPRF = (Pontine Paramedian Reticular Formation)

Medial longitudinal fasciculus

Abducens nucleus contains motoneurons and interneurons. They carry ALL the conjugate eye movement commands – saccade, pursuit, vestibular

Medial Vestibular Nuc-

horizontal vestibular commands
Saccades (FEF and PEF) and Pursuit (MST)
Generation of Leftward Saccades

Right Cerebral Hemisphere

PPRF (left)

SC

FEF

PEF

SC = superior colliculus
FEF = frontal eye fields (voluntary)
PEF = parietal eye fields (reflexive)
PPRT = paramedian pontine reticular formation
Generation of Rightward Pursuit

Right Cerebral Hemisphere

- FEF
- MST

CEREBELLUM
- dorsal vermis
- flocculus/paraflocculus

- NRTP/PN
- FN
- VN
- ABD nuc.

PN = pontine nuclei
FEF = frontal eye fields
MST = medial superior temporal area
NRTP = nuc. reticularis tegmenti ponti
VN = vestibular nuclei
ABD = abducens nucleus
FN = Fastigial nucleus

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LR = Left Hemisphere
MR = Right Hemisphere

Red arrows indicate inhibition.
Cerebral control of saccades and pursuit

- **SACCades**
  - Frontal Eye Fields (FEF) (voluntary) and Parietal Eye Fields (PEF) (reflexive) generate CONTRALATERAL saccades
  - Pathways – Project to superior colliculus and then CROSS to contralateral PPRF (which generates ipsilateral saccades and projects to the abducens nucleus)

- **PURSUIT**
  - Area MST (at parietal temporal junction) generates IPSILATERAL pursuit
  - Pathways – Project to cerebellum (flocculus and paraflocculus (tonsil) and dorsal vermis), and then to the brainstem and abducens nucleus
Conjugate gaze deviations with acute lesions

Cerebral hemisphere lesions: each hemisphere controls conjugate gaze (except pursuit) to the OPPOSITE side so the eyes typically deviate toward the side of the lesion (and AWAY from the side of the hemiparesis). (Remember the corticospinal tract crosses at the pyramids.)

Pontine lesions: each pons controls conjugate gaze to the SAME side so the eyes deviate away from the side of the lesion (and TOWARD the side of the hemiparesis). (Remember the corticospinal tract crosses at the pyramids.)
Burst neurons

**Horizontal (pons)**
- Paramedian pontine reticular formation (PPRF)

**Neural integrator**
- Medial vestibular nucleus/nucleus prepositus hypoglossi

**Vertical (midbrain)**
- Rostral interstitial nucleus of the MLF (riMLF)
- Interstitial nucleus of Cajal (INC)
Signal processing for normal and abnormal saccades

Note: For a normal saccade the pulse must be of the correct amplitude (height (velocity) x width (duration), i.e., area under the curve) and be matched to the correct size step.
Signal processing for normal and abnormal saccades

Note: For a normal saccade the pulse must be of the correct amplitude (height (velocity) x width (duration), i.e., area under the curve) and be matched to the correct size step.
Key Cerebellar Eye Signs

**NODULUS/UVULA**
- Prolonged rotational VOR
- Periodic alternating nystagmus (PAN)
- Impaired habituation of VOR
- Impaired tilt suppression of post-rotatory nystagmus
- Impaired translational VOR
- Downbeat nystagmus
- Impaired vertical pursuit
- Head-shaking nystagmus
- Contraversive OTR, skew

**FLOCCULUS/PARAFLOCCULUS**
(TONSIL)
- Downbeat, gaze-evoked, rebound, centripetal nystagmus
- Impaired smooth pursuit and cancellation of VOR
- Abnormal amplitude and direction of VOR head impulse response
- Alternating skew deviation
- Abnormal torsion with vertical pursuit (brachium pontis)

**FASTIGIAL NUCLEUS (FN)**
- Unilateral:
  - Hypermetric ipsiversive saccades
  - Hypometric contraversive saccades
  - Reduced contralateral initial acceleration of pursuit
- Bilateral:
  - Hypermetric saccades
  - Macrosaccadic oscillations
  - Normal pursuit
  - Exophoria
  - Saccade intrusions (square wave jerks)

**OCULAR MOTOR VERMIS (V,VI,VII)**
- Unilateral:
  - Hypermetric contraversive saccades
  - Hypometric ipsiversive saccades
  - Reduced initial acceleration of ipsilateral pursuit
- Bilateral:
  - Hypometric saccades
  - Reduced initial acceleration of pursuit
  - Esophoria (greater at distance, “divergence paralysis”)
Cerebellar control of eye movements: The basics and the latest

Anatomical localizations:
Flocculus/paraflolocculus (gaze-holding, pursuit, fast vestibular responses)
  Gaze-evoked, rebound, downbeat nystagmus
  Abnormal amplitude and direction of VOR
  Impaired pursuit and VOR cancellation
  Impaired translational VOR
  RX 4-aminopyridine for nystagmus
Nodulus (sustained vestibular responses)
  Periodic alternating nystagmus (PAN RX baclofen +/- memantine
  Positional nystagmus (downbeat, torsion)
  Head-shaking nystagmus
  Contralateral OTR
Dorsal vermis/posterior fastigial nucleus (Saccade accuracy, eye alignment)
  Saccadic hypometria (vermis) / hypermetria (fastigial nucleus)
  Esodeviation at distance (“divergence paralysis”)
  Saccadic intrusions (?fastigial nucleus): RX memantine
Middle Cerebellar Peduncle
  Torsional nystagmus during vertical pursuit
Other common signs with less certain localization
  Skew deviation that alternates on lateral gaze (abducting eye usually higher)); Impaired translational VOR
A Phone Call from an Acutely Vertiginous Patient: Key Diagnoses

**Stroke**
- Headache,
- Neck pain,
- Other neurological symptoms (diplopia, numbness, weakness, hiccoughs, dysphagia, dysarthria, incoordination),
- Acute unilateral hearing loss or tinnitus,
- Risk Factors (age, hypertension, lipid disorder, heart disease, diabetes)

**BPPV**
- Positional, usually turning over or getting in and out of bed,
- Transient, recent inciting events (dentist, hairdresser, trauma, bed rest),
- Happened before?

**Vestibular Neuritis**
- Sustained vertigo even when at rest though worsened by movement
- Nausea and vomiting
- Hearing normal,
- Preceding viral illness

**Vestibular Migraine**
- Headache, family history of migraine,
- HAs may only be remote,
- Vestibular symptoms and HA often dissociated.
- Triggers, aura, light, noise, motion sensitivity
- Relieved by sleep

**Menieres**
- Aural symptoms (pain, pressure, fullness in ear, seashell tinnitus, fluctuating hearing loss (low frequency))
- Diplacusis
- Attacks last hours
- Otolithic crises of Tumarkin
- Vertigo direction may reverse
- Lermoyez (hearing improves as vertigo begins)
The Acutely Vertiginous Patient: Key Findings

**Stroke**
- Spontaneous jerk nystagmus that does not suppress with fixation
- Gaze-evoked, direction-changing nystagmus
- Skew deviation (test sitting up)
- Absent head impulse sign (though if present does not rule out stroke (esp AICA))
- Other neuro signs
- New hearing loss
- HINTS (HEAD IMPULSE negative, NYSTAGMUS changes direction on R and L gaze, TEST for SKEW)

**BPPV**
- Positioning nystagmus, transient, after a latency, usually mixed vertical torsional if posterior canal or horizontal if lateral canal.
- Posterior canal BPPV changes direction on sitting up.
- Lateral canal may be apogeotropic (beats to sky) or geotropic (beats to ground). In head position when most intense, beats to involved ear

**Vestibular Neuritis**
- Spontaneous, sustained, mixed horizontal-torsional nystagmus in straight ahead gaze.
- Obey Alexander's law (more intense with gaze in the direction of quick phase)
- More intense when lying with bad ear down.
- Suppressed with fixation

**Vestibular Migraine**
- May mimic BPPV or Vestibular Neuritis or have central ocular motor signs (gaze-evoked or vertical nystagmus)
- Positional nystagmus is common

**Menieres**
- Spontaneous nystagmus similar to vestibular neuritis, suppressed by fixation
- Nystagmus may spontaneously change direction in the first minutes and then hours after onset.
- Loss of hearing, especially low frequency, Henneberts sign (tragal compression produces nystagmus)
Key questions in the acute vestibular syndrome

- Neurological symptoms? TIA/STROKE, MIGRAINE
- Headache or neck pain? STROKE, MIGRAINE
- History of head trauma or unusual head postures? BPPV, STROKE
- Any previous episodes? ALL except VESTIBULAR NEURITIS
- Duration of the spell?
  - Stroke/TIA: minutes to hours
  - Migraine: minutes to days
  - Meniere’s: hours
  - BPPV: seconds
  - Vestibular neuritis: days
- Is it positional? BPPV, MIGRAINE
- Hearing symptoms? MENIERES, MIGRAINE
- Vascular risk factors and age? STROKE
THE KEY PHYSIOLOGICAL PRINCIPLES UNDERLYING THE EXAMINATION OF THE VESTIBULO-OCULAR REFLEX: I

- Vestibulo-ocular reflexes assure clear vision when the head moves. The *rotational* vestibuloocular reflex (rVOR) produces slow-phases that compensate for head rotation: horizontal (yaw), vertical (pitch) or torsion (roll). The *translational* vestibuloocular reflex (tVOR) produces slow phases that compensate for head translation; side-to-side (interaural), fore and aft (anterior-posterior), or up and down (vertical).

- Normally with the head still, the left and right vestibular nerves and the vestibular nucleus neurons to which they project have equal resting discharge rates (vestibular tone). Head movement toward one side excites that labyrinth and inhibits the other.

- If the tone becomes relatively less on one side, either from a pathological lesion or a simulated lesion, e.g., caloric irrigation, the imbalance between *semicircular canals* produces a *spontaneous nystagmus* with slow phases directed toward the ‘lesioned’ side. The imbalance between the *utricles* produces an *ocular tilt reaction (OTR)* consisting of a lateral head tilt, vertical eye misalignment (skew deviation with the eye higher in the higher orbit), and ocular counterroll (torsion of both eyes with the top poles rotating toward the side of lower eye). There is also an accompanying perceptual tilt of the visual world (SVV, subjective visual vertical).
The intensity of nystagmus often depends on the position of the eye in the orbit (Alexander’s law). With peripheral lesions the slow-phase velocity is higher when gaze is in the direction of the quick phase. With central lesions the opposite sometimes occurs.

Nystagmus of peripheral origin is suppressed by visual fixation; nystagmus of a central origin is usually not.

A dynamic imbalance between the response from the two labyrinths during head rotation or translation produces a directional asymmetry in the compensatory slow phases. This is best appreciated with high-acceleration, high-velocity, and high-frequency stimuli because of Ewald’s second law; stimuli that excite the labyrinth produce a stronger response than those that inhibit it. With a loss of function in one labyrinth a greater response is elicited with rotation or translation to the intact than to the lesioned side.

The central vestibular system improves the brain’s ability to faithfully transduce low-frequency head motion, e.g., during prolonged, constant-velocity rotations. This is called ‘velocity storage’ and produces post-head-shaking nystagmus that appears with unilateral labyrinthine hypofunction.
Key maneuvers to elicit a unilateral labyrinthine hypofunction

• Eliminate fixation to see if there is a spontaneous nystagmus with slow phases directed toward the affected ear.

• Subjective visual vertical (SVV) with bucket test (deviates toward side of lesion), alternate cover test to elicit a skew deviation.

• Abnormal head impulse response: With a high acceleration rotation toward the affected ear there is an Impaired slow phase requiring a corrective saccade (directed oppositely) to the head movement).

• After horizontal head shaking there is a horizontal nystagmus with slow phases directed toward the affected ear.

• While applying vibration on the skull there is a nystagmus with slow phases directed toward the affected ear.
Key bedside maneuvers in the dizzy patient

- Blood pressure and pulse, lying and standing,
- Dynamic visual acuity (horizontal, vertical, roll)
- Eliminate fixation to bring out spontaneous nystagmus (occlusive ophthalmoscopy, Frenzel lenses)
- Alternate cover test to elicit a skew deviation
- Bucket test or double Maddox rod to elicit ocular torsion and deviation of the subjective visual vertical
- Valsalva maneuver against pinched nostrils and with closed larynx
- Compression on the tragus or increased pressure in the ear with a pneumatic otoscope
- Loud tones with an audiometer (Tullio’s phenomenon)
- Vibrator to the mastoids and vertex of the skull
- Hyperventilation
- Sustained head-shaking (horizontal, vertical, circular),
- Rapid, brief head rotations (head impulses) and translations (head heaves)
- Positional maneuvers
  - Dix-Hallpike for posterior canal BPPV
  - Right and left ear down for lateral canal BPPV
  - Head hanging for central downbeat nystagmus
Mechanisms of head-shaking induced nystagmus

Cupula decay

Velocity Storage Mechanism: Nystagmus outlasts the displacement of the cupula. ‘Velocity storage’ perseverates peripheral canal signals and so improves the ‘low-frequency’ response of the VOR.

To explain head-shaking induced nystagmus

- Recall Ewald’s second law: Excitation > inhibition
- After sustained back and forth excitation at a high speed, activity accumulates in the good direction
- When the head stops rotating the stored activity slowly discharges producing post head-shake nystagmus

Rotation at a constant speed in darkness

Raphan, Cohen.
Circular head-shaking to induce a post-rotatory torsional nystagmus that stimulates both vertical canals on one side (Bedside test of bilateral vestibular hypofunction)

Haslwanter, Minor 1999
Vestibular Neuritis

- **Superior Division** (lateral SCC, anterior SCC and utricle involved)
  - Spontaneous nystagmus: horizontal (beating toward the intact ear; lateral SCC), vertical torsional (with top pole beating toward intact ear and small* upward beating component; anterior SCC)
  - Abnormal head (rotational) impulse; lateral and anterior SCC planes
  - Abnormal o-VEMPs (ocular vestibular evoked myogenic potentials); utricle
  - Abnormal head heave (translational, side to side); utricle
  - Abnormal caloric; lateral SCC
  - Abnormal ocular counter-roll and a tilt of the SVV toward the side of the lesion, skew with ipsilateral eye lower; utricle

- **Inferior Division** (posterior SCC and saccule involved)
  - Spontaneous nystagmus: vertical-torsional with top pole beating toward intact ear and a downward beating component; posterior SCC
  - Abnormal head impulse; posterior SCC plane
  - Abnormal c-VEMPs (cervical vestibular evoked myogenic potentials); saccule
  - (occasional associated high-frequency hearing loss, basal cochlea)

* Relatively small vertical component with superior division since arises from intact, unopposed posterior SCC, which with its oblique orientation gives smaller vertical component
Fastigial nucleus (FN) facilitates contralateral saccades

Purkinje cells (PC) inhibit deep nuclei

Complex $R_{\text{cf}}$ and simple-spike $R_{\text{ss}}$ discharge of P-cells are inversely related

Lesion interrupts climbing fiber (CF) input from Inferior Olive (IO) to dorsal vermis

Simple-spike (inhibitory) discharge of P-cells increases

Fastigial nucleus (FN) activity decreases -- functional lesion

Saccades overshoot toward, undershoot away from, the lesion (Wallenbergs, IPSIPULSION)

LATEROPULSION of saccades

FUNCTIONAL lesion of the fastigial nucleus (FN)

Saccades overshoot away from, undershoot toward, the lesion (superior cerebellar peduncle lesion, CONTRAPULSION)
Wallenbergs: Posterior Inferior Cerebellar Artery (PICA) infarct: Vestibular and ocular motor findings

• Otolith syndrome (involvement of caudal vestibular nuclei)
  – Skew deviation -- eye lower on the side of the lesion
  – Head tilt -- to the side of the lesion
  – Ocular counterroll -- both eyes roll (top of eye) toward the side of the lesion
  – Disordered perceptions of verticality
  – Pulsion of the body (vestibulospinal) toward the side of lesion

• Saccade syndrome (interruption of climbing fibers (Inferior cerebellar peduncle) causing a functional inhibition of ipsilateral fastigial nucleus)
  – Lateropulsion of saccades (saccades overshoot toward (ipsipulsion) and undershoot away, from lesion side)
  – Vertical saccades deviate toward the side of the lesion
  – Under closed lids, deviation of the eyes toward the lesion side
Lateral canal BPPV: Facts

• Geotropic – When lying right ear down or left ear down, nystagmus beats toward the ground. Usually canalolithiasis

• Apogeotropic – When lying right ear down or left ear down, nystagmus beats away from the ground. Cupulolithiasis or canalolithiasis

• When the patient is lying on the side in which the nystagmus is most intense the nystagmus will be beating toward the affected ear, i.e., geotropic, with affected ear down and apogeotropic, with affected ear up

• Bow and lean test
  – In upright or head tilted back:
    • if geotropic, spontaneous nystagmus beats to normal side
    • If apogeotropic, spontaneous nystagmus beats toward affected side
  – With head pitched far forward, nystagmus reverses direction

• Treatment
  – Geotropic
    • Gufoni: sitting, then tilt toward INTACT ear (side with weaker nystagmus), then turn head 45 deg DOWN
    • Log rolling: supine, then head 90deg to affected side, then 360 deg toward intact side, then upright
    • Prolonged lying with affected ear up
  – Apogeotropic
    • Gufoni: sitting, then tilt toward AFFECTED side (side with weaker nystagmus), then turn head 45 deg UP
    • Horizontal head shaking, forward somersaults
    • May convert to geotropic, then treat as above for geotropic
    • Kim maneuver with vibration for cupulolithiasis
    • Prolonged lying with affected ear down, prolonged lying with affected ear up
Lateral canal orientation with head upright (side view)

Califano 2008

apogetropic

ampulla

gaeotropic

geotropic
Right lateral canal BPPV: Geotropic (beats to ground), with intensity greatest with bad (right) ear down

Nuti, 2012
Right lateral canal BPPV: Apogeotropic (beats to sky), with intensity greatest with good (left) ear down

Nuti, 2012
RX LC - BPPV - cupulolithiasis (apogetotropic) Kim, ‘12
Changes of nystagmus according to the otolith-attached side of the cupula during CuRM

Patient’s position during CuRM | Character and direction of nystagmus
--- | ---
| Canal side * | Utricular side *
1st position | Persistent apogeo, disappear after oscillation | Persistent apogeo regardless of oscillation
2nd position | Transient apogeotropic | Persistent apogeotropic
3rd position | Transient nystagmus beating to healthy side | No nystagmus
4th position | Transient geotropic | Persistent apogeo, disappears after oscillation
5th position | Transient nystagmus beating to healthy side | Transient nystagmus beating to lesion side

CuRM (cupulolith repositioning maneuver) for lateral canal BPPV due to cupulolithiasis (apogeotropic) (Kim 2012)
Image from the paretic (deviated) eye is projected in the direction of action of the paretic muscle.

Maddox Rod (in front of right eye in R SOP palsy)
Cover testing

• **COVER – UNCOVER**
  – a test for TROPIAS (misalignment with both eyes viewing)
  – TROPIAS are ABNORMAL
  – Look for the movement of redress (the corrective movement) when the cover is removed
  – Must always do for each eye.

• **ALTERNATE COVER**
  – a test for PHORIAS (misalignment with one eye viewing)
  – PHORIAS, especially if vertical may be ABNORMAL but normals, when viewing a near target, frequently have horizontal phorias (usually exo)
  – Look for the movement of redress (the corrective movement) when the cover is switched
“Comitancy”

• Comitant deviations – ocular misalignment is independent of the direction of gaze. Also called nonparalytic deviations.
  – Typical cross-eyes of childhood.
  – Many normals have comitant horizontal phorias (usually exo but may be eso).
• Non-comitant deviations – ocular misalignment varies with the direction of gaze. Also called paralytic deviations.
  – Muscle paralysis (III, IV, VI)
  – Orbital restriction (e.g., tumors, thyroid)
  – Myasthenia gravis, inflammatory myositis
The ‘facts’ about vertical muscle actions

• Superior oblique and inferior rectus muscles depress the eye.
• Inferior oblique and superior rectus muscles elevate the eye.

• Superior oblique and superior rectus muscles are also intorters (top pole rotates toward nose).
• Inferior oblique and inferior rectus muscles are also extorters (top pole rotates away from the nose).

• In an adducted position the oblique muscles play a relatively greater role in vertical rotation of the globe than do the recti muscles.
• In an abducted position the vertical recti play a relatively greater role in vertical rotation of the globe than do the oblique muscles.

• The tertiary action of the oblique muscles is abduction.
• The tertiary action of the vertical rectus muscles is adduction.
TESTING of a vertical deviation as a four-stage procedure (e.g. LEFT IV palsy)

- Determine the side of the hypertropia (Left higher)
- Determine whether the deviation is greater in right or left gaze (Right gaze)
- Determine whether the deviation is greater in up or down gaze (Down gaze)
- Determine if the deviation increases with head tilt to the right or left shoulder (the Bielschowsky head-tilt test) (Left shoulder)

![Diagram showing different gaze positions and head tilts]
NONcomitant, paralytic, deviation changes with orbital position
Does not change from upright to supine
More head tilt, eyes open

Comitant, nonparalytic, deviation independent of orbital position
May lessen from upright to supine
More head tilt, eyes closed
SKEW (OTR, ocular tilt reaction)  IV (SUPERIOR OBLIQUE PALSY)

SKEW
Higher eye intorted, lower eye extorted
Usually no or little torsional diplopia

SUPERIOR OBLIQUE PALSY
Higher eye extorted
Torsional diplopia (images point to paretic eye)
Slant (top of object appears closer)

C and D (Patient View)
Contributions to the pathophysiology of skew deviation

1. **Imbalance in static utriculo-ocular reflexes.** The normal response in a lateral-eyed animal to a lateral tilt of the head is a vertical divergence of the eyes (or skew) that helps to keep the retinal meridians aligned with the horizon. In a frontal-eyed animal the normal response to a lateral tilt of the head is counterroll but in pathological circumstances the phylogenetically-old response of lateral-eyed animals to a lateral tilt of the head could emerge as an unwanted vertical divergence of the visual axes, i.e. a skew.

2. **The axis around which the globes rotate.** In humans, the normal response (counterroll, torsion) to a lateral head tilt is in a head frame of reference, i.e., the eyes rotate around the anterior-posterior (naso-occipital) axis. If the eyes are moved into adduction by convergence, both eyes still counterroll (torsion) but the eye on the side of the lower ear also rotates down and the eye on the side of the upper ear up, producing a vertical divergence (and vertical diplopia). Convergence, however, normally decreases the static ocular counterroll response to sustained lateral head tilt which lessens the (unwanted) vertical divergence of the visual axes. See next slide for a diagram

3. **Imbalance in dynamic vertical translational otolith-ocular reflexes.** During lateral tilt of the head the orbits are also translated. If the axis of rotation bisects the interocular axis (i.e., through the nasion) the orbit on the side of the lower ear moves down and the orbit on the side of the higher ear up. The compensatory response of the translational VOR would then be a vertical divergence of the eyes with the eye on the side of the lower ear rotating up and the eye on the side of the upper ear rotating down. This response would increase as the eyes were increasingly converged. (NOTE, this is in the opposite direction and would counteract the vertical divergence produced by moving the eyes into an adducted position as produced by the mechanism discussed in 2).

4. **Imbalance in vertical semicircular canal-ocular reflexes,** emerging from differences in vertical vs. torsional actions of the muscles innervated by the primary projections of the vertical SCC (anterior SCC to ipsilateral SR and contralateral IO; posterior SCC to the ipsilateral SO and contralateral IR). E.g., with a loss of posterior canal function there would be a vertical divergence of the axes with the contralateral eye being relative higher (loss of inferior rectus input) and the ipsilateral eye relatively extorted (loss of superior oblique input). Remember that the vertical rectus muscles are better elevators and depressors than the oblique muscles and the vertical rectus pulling actions change relatively less with horizontal eye position. Thus skews can become noncomitant with asymmetric involvement of either the otolith or canal pathways.

5. **Imbalance in static otolith reflexes** emerging from the phylogenetically-old response of lateral-eyed animals to a static (forward or backward) pitch of the head, again to keep the retinal meridians aligned with horizon. With the eyes centered in the orbit, which is to either side in a lateral-eyed animal, the correct response to pitch is counterroll. With the eyes rotated conjugately to the right or the left, however, the correct response must also include a vertical divergence with the abducting eye being higher to pitch backwards and the adducting eye being higher to pitch forward. In a frontal-eyed animal this creates a vertical divergence that changes sense depending on looking to the left or to right, i.e., an alternating (depending on right or left gaze) skew deviation.

Cartoon showing vertical skew after a roll head rotation from Migliaccio, Vision Res, 2006. The top traces show how the eye and head coordinate systems are misaligned during near viewing; thus, during near viewing a purely torsional eye rotation in head coordinates has torsional and vertical components in eye coordinates. The middle traces depict the positions of the left and right eyes just before roll rotation of the head when viewing a near target and both eyes are adducted equally. The bottom traces shows the final position of the eyes after a clockwise roll head rotation. Note the eyes are in a space-fixed view and the angles are exaggerated. The expected response of the torsional VOR is to rotate both eyes around the naso-occipital axis in the ccw direction (the compensatory direction), which produces a difference in vertical eye position as reflected in the different locations to which the foveae point.
## Muscle Actions

<table>
<thead>
<tr>
<th>MAN</th>
<th>RABBIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>primary action</strong></td>
<td><strong>secondary actions</strong></td>
</tr>
<tr>
<td>superior rectus</td>
<td>elevation</td>
</tr>
<tr>
<td>inferior rectus</td>
<td>depression</td>
</tr>
<tr>
<td>superior oblique</td>
<td>intorsion</td>
</tr>
<tr>
<td>inferior oblique</td>
<td>extorsion</td>
</tr>
<tr>
<td>medial rectus</td>
<td>adduction</td>
</tr>
<tr>
<td>lateral rectus</td>
<td>abduction</td>
</tr>
</tbody>
</table>

Simpson, Graf, ANYAS, 82
Ocular Tilt Reaction (OTR) PATHWAY
Utricle - Vestibular Nuclei – MLF - III, IV - INC

Wallenberg Laby/VIII N.
EYE LOWER on side of lesion, IPSI TILT

EYE HIGHER on side of lesion, CONTRA TILT

INC- midbrain

Utricle
Vestibular nuclei
Abnormal “heave” sign (translational VOR)  OTR (ocular tilt reaction), ocular counterroll and skew
Vertical misalignment (skew) in the OTR: Emergence of a phylogenetically-old, ocular righting response to lateral tilt

In the lateral-eyed rabbit, a lateral tilt (one ear up and the other down) leads to the eyes rotating around the roll axis with one eye rotating down and the other up (a physiological skew as part of a normal OTR)
Stimulate Left Utricular Nerve

RE

LE

Cat, Suzuki
In normal, frontal-eyed, foveate animals the normal response to a lateral head tilt is pure ocular counterroll or torsion, without a skew.

In pathology, in frontal-eyed, foveate animals the abnormal response to a perceived shift of the sense of vertical becomes a “compensatory” head tilt, counterroll and a skew that produces vertical diplopia.
Bilateral IV nerve palsies are characterized by

Relatively large amounts of **torsional misalignment** (tops of objects appear closer).

A vertical deviation that may change sense on right and left gaze and with right and left head tilt.

Must distinguish from the cerebellar vertical misalignment ('skew') which changes its sense with horizontal gaze but the ADducting eye is usually HIGHER vs. bilateral SOP palsy when ABducting eye is always HIGHER.

A relatively greater 'eso' deviation with down gaze ('V' pattern esodeviation). (Due to tertiary abducting action of the SO muscle)

Common cause: Frontal head trauma (motorcycle).
Table 9-8. DIAGNOSIS OF NUCLEAR OCULOMOTOR NERVE PALSY

OBLIGATORY LESIONS
Unilateral third nerve palsy with contralateral superior rectus paresis and bilateral partial ptosis
Bilateral third nerve palsy associated with spared levator function (Internal ophthalmoplegia may be present or absent)

POSSIBLE NUCLEAR LESIONS
Bilateral total third nerve palsy
Bilateral ptosis
An isolated weakness of any single muscle except the levator, superior rectus, and medial rectus muscles

CONDITIONS THAT ARE UNLIKELY TO BE DUE TO NUCLEAR LESIONS
Unilateral third nerve palsy, with or without internal involvement, associated with normal contralateral superior rectus function
Unilateral internal ophthalmoplegia
Isolated unilateral or bilateral medial rectus weakness
Unilateral ptosis
III NERVE NUCLEUS

(a) Caudal third
(b) Middle third
(c) Rostral third
(d) Rostral end
(e) Right lateral aspect
(f) Dorsal aspect

- CCN: Third Nerve Nucleus
- DN: Dorsal Nucleus
- VN: Ventral Nucleus

Legend:
- Rectus inferior
- Rectus medialis
- Rectus superior
- Obliquus inferior
- Levator palpebrae superioris
- Visceral nuclei