

Vestibular Physiology and Assessment of Vestibular Function

VESTIBULAR SYSTEM

The vestibular system is responsible for equilibration, coordination and orientation in space.

The anatomy of vestibular system comprises:

1. **The inner ear:** It contains the **receptor organs** in the semicircular canals (cristae), utricle and saccule (maculae).
2. The **superior and inferior vestibular nerves** (cranial nerve VIII): The superior vestibular N carries impulses from cristae of superior and lateral SCC and maculae of utricle whereas the inferior vestibular N carries impulses from cristae of posterior SCC (singular N) and maculae of saccule. These sensory nerves carry the information from these areas to the vestibular nuclei in the brainstem in the floor of the fourth ventricle. The cell bodies of these (Sup & inf vestibular N) 1st order neurons lie in the Scarpa's ganglion in the inner ear just lateral to the IAM.
3. **Vestibular nuclei:** The 2nd order neurons from here go to:
 - a. **Medial longitudinal bundle** or fasciculus (and through this connect with 3rd, 4th & 6th ocular nerves nuclei). The 3rd order neurons from here are the motor neurons and supply the ocular muscles. This completes the reflex arc for the vestibulo-ocular reflex (VOR). Defect in this pathway can be assessed by studying the kind of nystagmus.
 - b. Anterior horn cells of the spinal cord through **vestibulo-spinal** and other pathways. The 3rd order neurons from here are motor to the postural muscles of neck, trunk and limbs. This completes the reflex arc for the **vestibulo-colic** reflex. One of the ways by which the defect in this pathway can be assessed is by doing cVEMP studies.
4. Also from the vestibular nuclei there occurs to and fro (afferent as well as efferent) flow of information to the cerebellum (via **vestibulo-cerebellar pathway**), cerebral

cortex and reticular activating system. These upper or central connections, like elsewhere in neurology, are predominantly inhibitory to the contralateral vestibular nuclei. So, lesions here will lead to a hyperactive response on the contralateral side leading to vertigo which is labelled as central.

However, lesions of the inner ear receptors, vestibular nerves and the vestibular nuclei will lead to a hypoactive response on the ipsilateral side leading to vertigo which is labelled as peripheral. These two can be distinguished by studying the kind of nystagmus.

VESTIBULAR PHYSIOLOGY

The **receptor organ** consists of the following (also *see* chapter on anatomy of ear):

1. **Maculae** containing otolith (for sensing linear movements, gravitational and head tilt movements) within the utricle and saccule.
2. **Cristae** containing cupula (for sensing angular movements) within the semicircular canals.

The receptor organs detect the position and movement of the head in space. This information is converted into electrical signals that travel along the vestibular nerve to the vestibular nuclei in the brainstem. As mentioned above, the vestibular nuclei receive the signals and send messages to the following:

- i. To the spinal cord via the **vestibulospinal tract** for the regulation of muscle tone of the neck and limbs and thereby facilitating postural and righting reflexes.
- ii. To the eyes via the medial longitudinal fasciculus (**vestibulo-ocular tract**) to control the eyeball movement (with cranial nerves III, IV, and VI). This helps one's gaze to get fixed on one object (i.e., the image keeps falling on the most sensitive part of the retina, i.e., Fovea) as the head moves. This is called vestibulo-ocular reflex. It can be tested by caloric test and head impulse test.
- iii. To the cerebellum via the **vestibulo-cerebellar** tract to maintain coordination of the eyes, neck, body, and limbs in relation to position and movements of the head.
- iv. To the reticular formation in the brainstem and thereby preparing the autonomic nervous system.
- v. To the cerebral cortex via the thalamus for conscious perception of position.

Under normal circumstances, the impulses reaching the brain from all the above systems from both the sides are **equal and**



Note

Please note that though vestibular nuclei are classified anatomically as part of the central vestibular system, functionally their lesions will be like lesions of inner ear receptors and vestibular nerves. Therefore, in all the further discussions below they are being considered in the peripheral vestibular system.

opposite and help to maintain the balance of a person. However, any mismatch in the impulses reaching the brain (from these systems) can lead to vertigo.

VERTIGO AND ASSOCIATED SYMPTOMS

Vertigo or dizziness is the sensation of movement (most commonly rotational) and is often accompanied by feeling of loss of balance. When the vertigo is severe, it may be accompanied by autonomic manifestations, e.g., nausea, vomiting, sweating and palpitations. In most instances vertigo is also accompanied by spontaneous nystagmus. All these clinical manifestations can be easily understood as per the central connections of the vestibular system as discussed above.

Vertigo can occur either due to a peripheral vestibular pathology (inner ear receptor, vestibular nerves, vestibular nuclei) or a central vestibular pathology (involving the vestibular interconnections with cerebellum, cortex and reticular activating system).

LOCATING THE CAUSE OF VERTIGO (PERIPHERAL/CENTRAL)

To locate the pathology causing vertigo (peripheral or central), the following are done:

1. **Spontaneous nystagmus:** Nystagmus is involuntary oscillatory movement of eyeball.

Spontaneous nystagmus means movement of the eyes without a cognitive, visual or vestibular stimulus. This nystagmus occurs due to the difference in the normal **equal and opposite** activity of the vestibular systems of the two sides, as discussed above. If nystagmus is present spontaneously, it indicates an organic lesion. So spontaneous nystagmus is also called pathological nystagmus.

Nystagmus may be of two types:

- a. **Jerk or biphasic** (more common): Here rhythmic eye oscillation is characterized by a slow drift of the eyes in one direction that gets repeatedly corrected by fast movements in the reverse direction, i.e., jerk nystagmus has a **slow component followed by a fast component**. Conventionally the **direction** of the nystagmus is described as per the direction of its **fast component**.
- b. **Pendular** (less common): It is a sinusoidal eye oscillation with equal velocity in each direction.

As discussed previously *pathologic or spontaneous jerk nystagmus*, which is also an accompaniment to vertigo is due to an **acute asymmetry in vestibular activity, either peripheral or central**. By the characteristic of nystagmus we can have an idea whether the cause is peripheral or central, see Tables 3.1 and 3.3.

Table 3.1: Important differentiating features between peripheral and central nystagmus include the following (see Table 3.3 for further differentiating features)

Characteristics of spontaneous nystagmus	Peripheral vestibular	Central vestibular
Form (further elaborated in Table 3.2)	Torsional (i.e., rotatory movement of the eye globe about its anteroposterior axis) component superimposed on a horizontal (left or right movement) or vertical (downbeat or upbeat) nystagmus.	Pure horizontal, pure vertical or purely torsional nystagmus.
Direction	Direction-fixed, i.e., unidirectional nystagmus. The nystagmus becomes more pronounced with gaze towards the side of the fast component.	Direction changing, i.e., bidirectional. Here the direction of the fast component gets directed toward the side of gaze (e.g., left-beating in left gaze and right-beating in right gaze).
On visual/optic fixation	The nystagmus disappears with visual fixation. On removing the visual fixation, the nystagmus reappears. If the nystagmus is very fine, i.e., difficult to be seen by naked eye, then Frenzel glasses, which are strong convex glasses, are used. These glasses allow the examiner to see the patient's eyes greatly magnified. These glasses at the same time remove visual fixation, by blurring the patient's vision, thereby making the nystagmus apparent.	
Associated features	Unilateral Tinnitus and deafness is often present, but without any other cranial nerve and cerebellar involvement.	Besides tinnitus and deafness (indicating the involvement of 8th nerve), involvement and deficits of cranial nerves III to XII which are closely associated with the brainstem are often present. Also cerebellar manifestations (e.g., ataxia, dysarthria, etc.) may be seen.
Common causes	BPPV, Labyrinthitis, Vestibular neuronitis, Meniere's, Labyrinthine fistula and damage by ototoxic drugs.	Vertebrobasilar insufficiency and other central vascular conditions, Demyelinating illnesses and tumors.

Table 3.2: The different forms and directions of spontaneous nystagmus in various central and peripheral pathologies

Forms and direction of nystagmus	Peripheral irritative lesion	Peripheral destructive/paretic lesion	Central
Horizontal with torsion	Horizontal (lateral) canals, nystagmus toward ipsilateral side	Horizontal (lateral) canals, nystagmus toward opposite side	—
Vertical upbeat with torsion	Posterior semicircular canal (in BPPV), read below	Superior semicircular canal	—
Vertical downbeat with torsion	Superior semicircular canal	Posterior semicircular canal	—
Pure torsional	—	—	Medullary lesions
Pure vertical upbeat	—	—	Medullary lesions
Pure vertical downbeat	—	—	Vertebrobasilar insufficiency, Craniocervical anomalies (Arnold-Chiari Malformation) and drug intoxications
Pure horizontal	—	—	Unilateral disease of the Cerebral hemispheres
Pendular	—	—	Brainstem or Cerebellar dysfunction

So a spontaneous nystagmus with fixed direction, which has an additional superimposed rotatory component and which disappears with visual fixation is due to peripheral vestibular pathology. The direction of this nystagmus is important as it helps in finding the nature of pathology of the peripheral vestibular system (which may be irritative or destructive), *see below*.

The significance of the direction of jerk nystagmus: Under normal circumstances, the vestibular system of the right side pushes the eyeball to the left, whereas the vestibular system of the left side pushes the eyeball to the right. If the **right peripheral vestibular system becomes hypoactive due to any destructive/paretic pathology**, then due to unopposed action of the left vestibular system, the eyeball tends to slowly move to the right. Subsequently due to corrective central compensatory mechanism (the brainstem mechanism involving the medial longitudinal fasciculus), the eyeballs quickly return to their initial location, i.e., toward the left (fast phase).

This goes on repeatedly resulting in nystagmus.

In the above example, the fast component being toward the normal side (left), so we should remember that a destructive peripheral pathology of one side vestibular system leads to a nystagmus toward the opposite (normal) side.

Whereas if the **right vestibular system becomes overactive, due to any irritative pathology**, it will lead to excessive pushing of the eyeball toward the left (slow phase). Again due to central compensation the eyeballs quickly return to their initial location, i.e., toward the right (fast phase).

This leads to nystagmus (fast component) toward the side of irritative lesion.

As mentioned in Table 3.1, in the above examples, there is an additional torsional component besides horizontal movements.

To summarize: The slow component of nystagmus is by virtue of disease. The fast component is the corrective phase to bring the eyeball back to midline. Direction of nystagmus is named after the direction of the fast component as the fast component is more obvious on clinical examination.

By the direction of the nystagmus in peripheral pathologies, we can have an idea of the cause:

- i. In **irritative lesions (overstimulation)** of the labyrinth like BPPV, serous labyrinthitis, fistula of labyrinth, etc., the nystagmus is toward the ipsilateral side, i.e., the side of the lesion (easy to remember **I** for **I**; Irritative – Ipsilateral) and the nystagmus is in the plane of the excited semicircular canal (vertical for vertical canals, i.e., superior and posterior and horizontal for horizontal canal)
- ii. In destructive or **paretic lesions**, e.g., vestibular neuritis, purulent labyrinthitis, trauma to labyrinth, section of vestibular nerve, etc. the nystagmus is toward the opposite side, i.e., normal side (easy to remember **P** for **P**; Paretic–opposite). The nystagmus here is horizontal and tortional.

Each semicircular canal (SCC) has a synergistic canal on the opposite side lying approximately parallel to it. The horizontal canals act as a pair, while each superior canal is paired with posterior canal on the opposite side.

The superior SCC stimulation leads to the contraction of ipsilateral superior rectus and the contralateral inferior oblique making the eyes move vertically up. The posterior SCC stimulation leads to the contraction of ipsilateral superior oblique and contralateral inferior rectus making the eyes move vertically down. The horizontal SCC stimulation leads to the contraction of ipsilateral medial rectus and the contralateral lateral rectus making the eyes move horizontally to the opposite side. Usually the action is equal and opposite in both eyes, hence no nystagmus. Because of the action on the eye muscles as mentioned above, involvement of the **horizontal, i.e., lateral semicircular canal leads to horizontal tortional nystagmus** whereas involvement of the vertical canals, i.e., superior and posterior semicircular canals leads to **vertical tortional nystagmus**. When one side labyrinth is destroyed, the action of only the normal labyrinth prevails. With the stimulation of the normal labyrinth, the stimulation of the respective muscles of that eye occurs. The action of superior rectus (elevation, adduction, intortion) and superior oblique (depression, abduction, extortion), being equal and opposite cancels with only intortion and action of medial rectus remaining. This leads to the horizontal and tortional movement of the eye with slow component to the defective side and fast component to the normal side.

Mnemonic: Nystagmus is always toward the more active side.

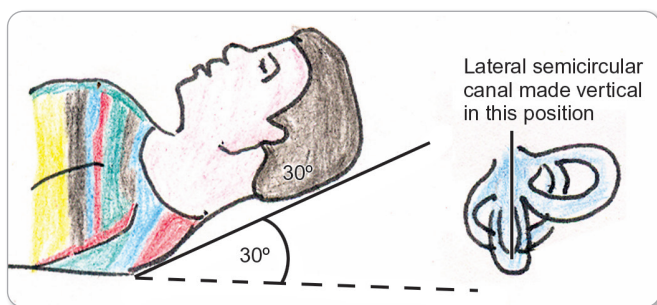


Fig. 3.1: Position of caloric test

In **destructive lesion of right** labyrinth, more active is the normal ear, i.e., left side, so nystagmus is to normal side, i.e., left.

In **hyperactive lesion of the right** labyrinth, more active is the affected side, i.e., right side, so nystagmus will be toward right.)

2. Induced nystagmus:

If spontaneous nystagmus is not present, then nystagmus can be induced for evaluating the cause of vertigo (peripheral or central). This can be done by:

- I. **Caloric test:** Thermal changes in the EAC can induce convection currents in the horizontal (lateral) SCC (bulge of which is present on the medial wall of middle ear). Caloric test is a clinical test of the vestibulo-ocular reflex (head impulse test also studies this reflex, read below) by thermal stimulation of the lateral SCC (Fig. 3.1).

The lateral or horizontal SCC is maximally responsive when it is in the vertical position. It can be placed in vertical position by seating the patient with head tilted 60 degrees backward or raising the head 30 degrees forward in supine position.

In this test, we can test the vestibular system of each ear separately. However, since only the lateral SCC is being stimulated here so only the superior vestibular nerve which supplies it (see Chapter 1), can be tested.

There are two types of caloric tests:

- a. **Modified Kobrak test:** This is also known as minimal cold stimulation test because this test is done initially with 5 mL ice cold water. With this minimal ice cold water, the patient's ear is irrigated after seating the patient with head tilted **60 degrees backward**. Normally nystagmus toward opposite ear is seen with 5 mL of ice cold water. If no response occurs even with 40 mL ice cold water, it indicates dead labyrinth. If response is seen with increased quantities of water between 5 and 40 mL, labyrinth is considered hypoactive.
- b. **Fitzgerald Hallpike test (Fig. 3.2):** This test is also known as **bi-thermal caloric test** because it is tested with **cold (30°C)** as well as **warm (44°C)** water, i.e., 7 degrees below and above the normal body temperature of 37°C.

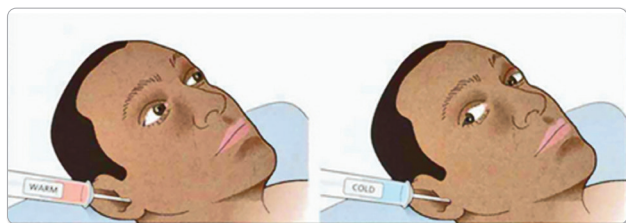


Fig. 3.2: Fitzgerald Hallpike test

The procedure is done in the following order with each irrigation lasting for 40 seconds:

Left cold → right cold → left warm → Right warm

An interval of 8 minutes is given in between each irrigation for the temperature to come back to normal.

Here the patient lies supine with head raised **30 degrees forward** to make lateral (or horizontal) semicircular canal vertical in which it is maximally responsive and the ears are irrigated with 30° and 44° water for 40 seconds with a gap of 8 minutes in each in the order mentioned above (Fig. 3.2).

Here the normal response is **C O W S**, i.e., with **C**old water (cold water makes the labyrinth hypoactive/paretic) nystagmus is toward the **O**pposite side and with **W**arm water (warm water makes the labyrinth hyperactive/irritative), it is toward the ipsilateral, i.e., **S**ame side. The normal response in a caloric vestibular test is symmetric in the two ears.

Utility of caloric test:

- i. Each labyrinth can be tested separately. This test can tell us unilateral paretic/dead or irritative labyrinth.

In **paretic/dead labyrinth, no/hypoactive response** is seen.

A directional preponderance usually signifies a central pathology, though it is not specific and can also be seen in lesions of the labyrinth, hence has very little clinical significance. (A right directional preponderance means a stronger right beating nystagmus which is the sum total of left cold water and right warm water response. Similarly, a left directional preponderance means a stronger left beating nystagmus which is the sum total of right cold water and left warm water response).

- ii. The following characteristics of the nystagmus (in addition to those mentioned in Table 3.1), elicited by the caloric test, help to distinguish between a peripheral and central vestibular pathology. Since the central pathways have an inhibitory control on the peripheral vestibular system, therefore, with central lesions there is loss of inhibition leading to such characteristics, e.g., no latency, no fatigability, no disappearance with visual fixation and prolonged duration of the nystagmus.

Table 3.3: Differences between peripheral and central nystagmus

	Peripheral nystagmus	Central nystagmus
Latency (It is the time taken for the nystagmus to start while testing for it).	2–20 seconds	No latency
Duration	Less than 1 minute	More than 1 minute
Fatigability (It is the inability to elicit nystagmus on repeating the test again and again).	Fatigable	Non-fatigable

- iii. Since the caloric test assesses the vestibulo-ocular reflex arc and the vestibular and ocular nuclei are lying in the brain stem, therefore, absent caloric test is a very useful bedside test to look for brain death in comatose patients so that their organs can be used for transplantation.

1

CLINICAL CASE QS

In a patient of suspected vestibular destruction, the following test was done. Which of the following is not true of this test?



- It stimulates the lateral SCC by thermal stimulation.
- Normally cold water induces nystagmus to opposite side and warm water to same side.
- In canal paresis there is no nystagmus.
- The induced nystagmus disappears on removal of optic fixation.

2

CLINICAL CASE QS

The test in clinical case 1 is done at what temperature:

- 30° and 44°
- 34° and 41°
- 33° and 21°
- 37° and 41°

- II. **Cold air caloric test:** In patients with TM perforation where irrigation with water cannot be done, cold air is blown into the ear by passing ethyl chloride through a coiled copper tube known as Dundas Grant tube.
- III. **DIX-Hallpike maneuver:** This is a maneuver to rule out BPPV (benign paroxysmal positional vertigo) which is the most common cause of peripheral vertigo.

BPPV is a condition in which dislodged otoconia/debris, moves from the utricle most commonly into the **posterior semicircular canal**.

Movement of these particles in head positions, which make the posterior semicircular canal to come in dependent position, stimulates the cupula of the **posterior semicircular canal** leading to vertigo.

This vertigo disappears when the debris settles down in 10–20 seconds.

These vertigo attacks reappear with change of head position making the posterior SCC dependant again.

To diagnose posterior canal BPPV the positional test or **Dix Hallpike** maneuver is done.

As shown, to test the **posterior semicircular canal of the right ear** the patient's head is turned 45 degrees right while sitting on the examination table and then the patient is made to lie supine with his head turned right hanging 30 degrees below the horizontal. The test is repeated with head turned to **left to test the posterior semicircular canal of the left ear**.

If while doing this maneuver, **vertical upbeat nystagmus with outwards torsion**, i.e., **upbeating geotropic-torsional nystagmus** with the typical features of peripheral pathology as mentioned in Tables 3.1 and 3.3 above, appears then it is reported to be positive, i.e., the patient has BPPV.

(e.g., if the **right posterior semicircular canal** is involved, upon making the patient lie supine with head tilted toward right, i.e., **right ear facing the ground**, there will be **vertical torsional nystagmus toward the hyperactive**, i.e., the **right ear**, which is now **facing the ground i.e., geotropic**).

Horizontal canal BPPV is diagnosed by 'roll test'. The head is flexed 30 degrees and then briskly rolled to one side. The same is repeated to the opposite side. In majority of the cases the nystagmus will be horizontal and geotropic toward the ear being tested, i.e., the undermost ear. When the head is turned to the opposite side, the nystagmus will again beat toward the undermost ear. The side on which a brisker nystagmus is seen is the affected side (Figs 3.3 and 3.4).

TREATMENT OF BPPV

The treatment of posterior canal BPPV is the canalith repositioning maneuver known as **Epley's maneuver** (Figs 3.3 and 3.4).

As shown, in this maneuver the patient's head is moved into different positions in a sequence that will move the debris from the semicircular canal back into the utricle. Also see BPPV in Chapter 12 on "Meniere's disease and disorders of vestibular system".

The horizontal canal BPPV is managed by **repositioning** maneuver known as Gufoni maneuver or the 270 degree 'Barbecue maneuver'.

3

CLINICAL CASE QS

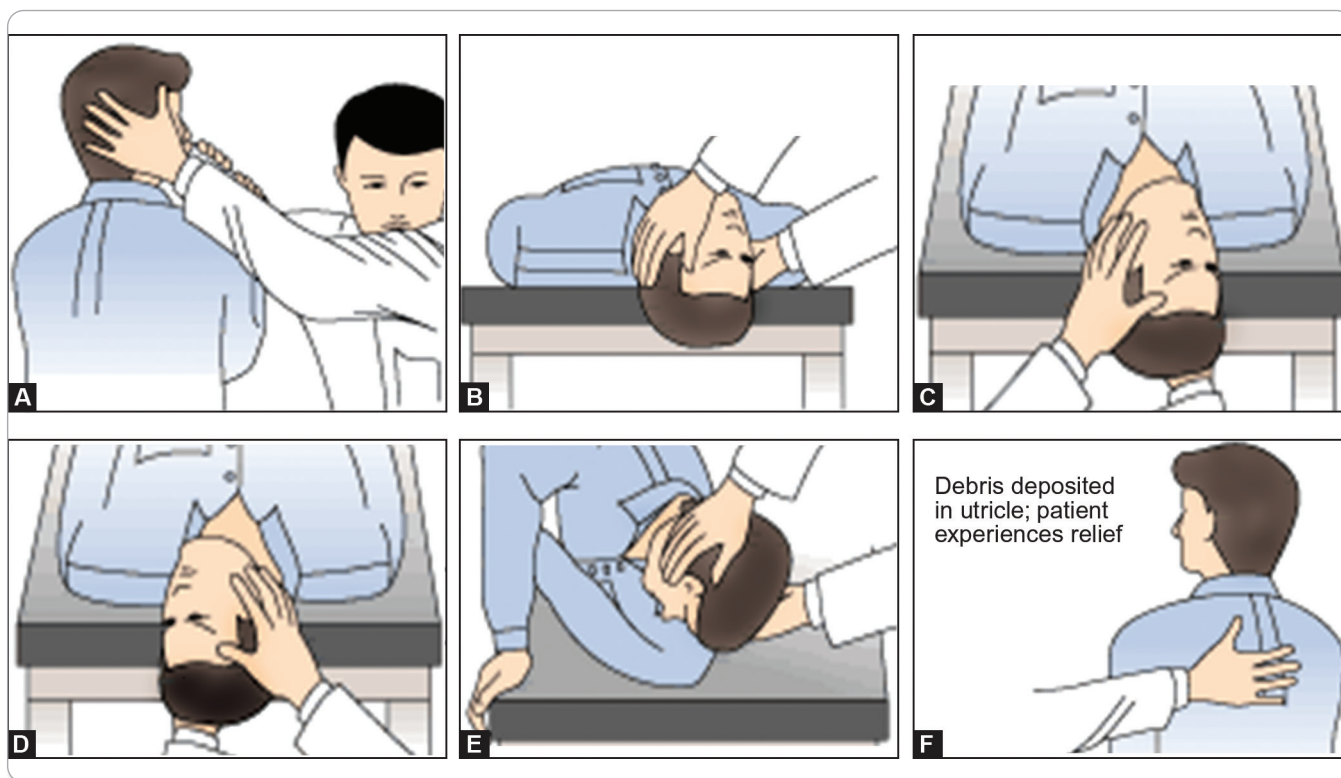
A 30-year-old presents with vertigo. The vertigo is episodic lasting for few seconds, while turning only to left. Hallpike was performed and a nystagmus was seen while tilting the head to the left side. What will not be the characteristic of this nystagmus?

- It has a latency
- It will disappear after some time duration
- It is fatigable
- It is vertical and torsional with direction to the left
- It will enhance on optic fixation
- It will disappear by Epley's maneuver

OTHER TESTS TO ASSESS VESTIBULAR FUNCTION

Fistula Test

Whenever pressure changes are done in EAC by pressing and releasing the tragus alternately or by using Siegel's speculum, this pressure change is transmitted to the middle ear through the TM but not to the inner ear.

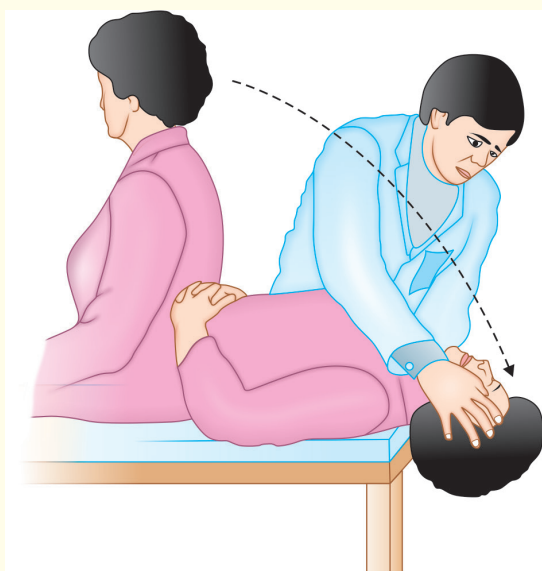


Figs 3.3A to F: Epley's maneuver

4

CLINICAL CASE QS

A 35-year-old female presents to the OPD with episodic vertigo. The doctor performed the given maneuver. The given maneuver is used to:



- Assess vestibular function
- Differentiate cochlear and retrocochlear deafness
- Assess cerebellar function
- Find out lateral semicircular canal fistula



Fig. 3.4: Epley's maneuver

But whenever there is an abnormal communication (fistula) on the medial wall of middle ear connecting the middle ear to inner ear, e.g., promontory cochlear fistula, erosion of lateral semicircular canal, fistula on the oval window, round window rupture, etc., the change in pressure of the EAC will get transmitted to the inner ear leading to stimulation of labyrinth and vertigo and nystagmus.

In any patient complaining of vertigo on changing the pressure of EAC, the presence of fistula on medial wall can be diagnosed.

This test is known as fistula test.

Previously in otosclerosis fenestration operation used to be done. It is a procedure of making an opening/fenestra over the lateral semicircular canal. This was an **iatrogenic cause of positive fistula test**.

Another iatrogenic cause of positive fistula test is a fistula over the oval window that may follow stapedectomy done for otosclerosis.

Hence **fistula test is positive in ears with fistula on the medial wall of middle ear and negative in normal ears**.

False negative fistula test: If the fistula test is negative in spite of a fistula on the medial wall, it is known as false negative fistula test. The causes of false negative fistula test are the following:

- If the fistula on the medial wall is **covered by cholesteatoma** so that pressure is not transmitted to inner ear.
- Inner ear is dead** and does not respond to pressure change in spite of presence of fistula.

False positive fistula test/Hennebert's sign: If the fistula test (vertigo on changing the pressure of EAC) is positive in spite of no fistula on the medial wall it is known as false positive fistula test or Hennebert's sign. The causes of false positive fistula test are the following:

- If the **footplate of stapes is hypermobile** as in congenital syphilis, the footplate moves excessively on pressure changes and even stimulate the utricle and saccule, leading to vertigo and nystagmus.
- In **25% cases of Meniere's**, fibrous adhesions form between stapes footplate and utricle and saccule. The pressure changes of EAC will now get transmitted to these leading to vertigo and nystagmus (Hennebert's sign).
- In Superior semicircular canal dehiscence (SSCD), see Chapter 12.

5

CLINICAL CASE QS

Match the following:

- | | |
|--------------------------------|---------------------------|
| a. Fistula test positive | 1. Hennebert sign |
| b. Fistula test false positive | 2. Fenestration operation |
| c. Fistula test negative | 3. Otosclerosis |
| d. Fistula test false negative | 4. Dead labyrinth |
| | 5. Tullios phenomenon |

Head Impulse Test (Head Thrust Test)

This is another important OPD test (besides the caloric test) for testing the Vestibulo-ocular reflex (VOR). The VOR helps to stabilize our gaze on to an object during head movements in different directions, so that the image keeps falling over the Fovea of retina.

The patient is asked to keep looking at an object while his head is moved briskly and abruptly. Normally the eyes move in the opposite direction at the same speed as the head movement and will appear to remain fixed on the target. In the absence of VOR the eyes will lag behind and there will be jerky catch up movement (called saccades) of the eyes at the end of the head movement to reach the target.

In this test, the head is moved briskly 10–15 degrees in steps and eye movements are noted for catch up saccades. The components of this reflex are:

- The 6 SCCs (a particular SCC gets stimulated depending upon the direction of the head movement),
- Superior and inferior vestibular nerve, and
- The medial longitudinal bundle/fasciculus

So a defect at any of the above 3 sites can be picked up by this test. The head impulse/thrust test has an advantage over the caloric test in the sense that it can test each of the 6 SCCs separately, whereas in the caloric test only the 2 lateral (horizontal) canals can be tested.

The Head impulse test, nystagmus characteristics and test for Skew eye deviation, all of which is together known as **HINTS** (**HI**—Head impulse, **N**—Nystagmus, **TS**—Test for Skew eye deviation) can be used to differentiate a peripheral from a central cause of vertigo. (Skew deviation is a vertical misalignment of eyes caused by supranuclear lesion in the posterior fossa, e.g., ischemia of the brainstem or cerebellum. It is tested by alternately covering one of the patients eyes while the patient looks at the examiners nose and looking for any vertical corrective movement of the uncovered eye).

6

CLINICAL CASE QS

In a patient of vertigo with suspected vestibular neuritis of the right side the following will not be seen-

- Horizontal Torsional nystagmus toward left
- This nystagmus will disappear by Optic fixation
- Direction of nystagmus will keep changing
- Head Impulse test will show saccades

Galvanic Test

In Galvanic vestibular stimulation test, electric current is delivered transcutaneously to the vestibular afferent nerves through electrodes placed over mastoid bones.

Here the **nerve endings** in all the semicircular canals, on one side, are **stimulated directly** by the current and not through the receptors, i.e., cupula.

Therefore, in patients in whom the caloric test, which tests the peripheral receptors, is negative, a response on galvanic stimulation indicates normally functioning vestibular nerves.

Vestibular Evoked Myogenic Potential (VEMP)

It is a test of the otolithic organs (utricle & saccule) and vestibulo-spinal pathway. This is in contrast to the caloric and head impulse test which involve SCCs and vestibulo-ocular pathways.

VEMPs are electromyographic (EMG) responses evoked by loud sounds.

Loud sounds cause strong movements of the oval window. Because of the close proximity of the oval window to the utricle and saccule, this strong movement stimulates the saccule and utricle also. From the **saccule**, the impulses are then carried by the **inferior vestibular nerve** to the vestibular nucleus and then through the vestibulo-spinal tract to the ipsilateral sternocleidomastoid muscle. This reflex to stabilize the head on the shoulders by stimulation of neck muscles whenever there is vestibular stimulation is known as vestibulo-colic reflex. The EMG recording of the sternocleidomastoid muscle with the help of surface electrode is called cervical VEMP or cVEMP. cVEMP are relaxation potentials recorded by surface electrodes placed on the skin of tonically contracted ipsilateral sternocleidomastoid muscle.

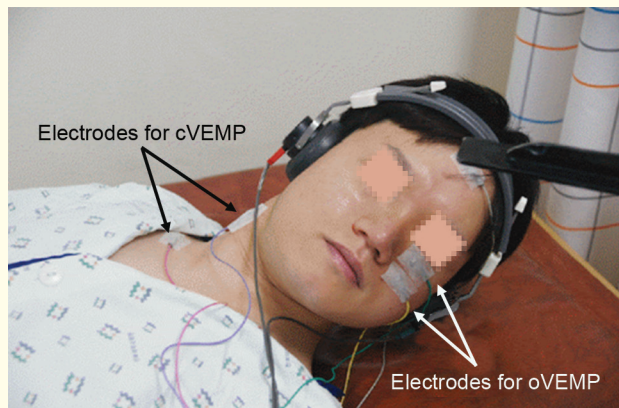
Similarly, from the utricle the impulses are carried by the superior vestibular nerve to the eye muscles of the opposite eye (EMG recording in the eye muscles will be called Ocular VEMP or oVEMP).

EMG recording of these muscular contractions (cVEMP and oVEMP) enables the clinician to document the status of utricle and saccule.

7

CLINICAL CASE QS

The given test was done in a patient of imbalance. True about this test is:



- If the cause of imbalance in this patient is SCC dehiscence, lower threshold and increased amplitude will be seen
- cVEMP will be absent or reduced in acoustic neuroma arising from the superior vestibular nerve
- cVEMP is the relaxation potential of ipsilateral sternocleidomastoid muscle
- It is a sound evoked vestibulospinal reflex

Clinical Usefulness of VEMP

- VEMP is an important test to find out the **nerve of origin of acoustic neuroma**.
- Significantly decreased amplitude on one side has been seen in conditions causing destruction of vestibular labyrinth or vestibular nerve like vestibular neuronitis, acoustic neuroma and Meniere's.
- Lower threshold and Increased amplitude of VEMP is useful in the diagnosis of superior semi-circular canal dehiscence syndrome where the labyrinth becomes more sensitive to loud sounds.

Unterberger Stepping Test

This is an OPD test to test the vestibular system. The maintenance of balance occurs due to the inputs to the CNS from three main systems, viz., the visual, the somatosensory or proprioceptive and the vestibular. In Untenberger test, the patient is blindfolded (to remove the visual input) and is asked to step on a spot approximately 90 times in a minute (to remove the proprioceptive input). The patient now maintains balance with the help of vestibular input from both sides. An inequality in the vestibular inputs, where one labyrinth is hypoactive will result in the normal side becoming more active and pushing the patient to the opposite side resulting in the patient deviating and rotating to the affected (weaker) labyrinth. A deviation of more than 70 degrees to right and more than 50 degrees to left is considered pathological. Any sway from side to side of more than 15 degrees is pathological and suggest a central lesion.



Multiple Choice Questions

1. A patient presented to the ENT OPD with the complaint of vertigo with no hearing loss. The doctor performed a diagnostic maneuver and then performed a therapeutic maneuver. Which is the diagnostic maneuver? (INI-CET 2020)
 - a. Dix Hallpike maneuver
 - b. Epleys maneuver
 - c. Hamptons maneuver
 - d. Simons maneuver
2. True about central nystagmus: (Recent Exam 2017)
 - a. Duration not limited
 - b. Direction fixed
 - c. Latency present
 - d. Suppressed by visual fixation
3. Peripheral nystagmus true about is: (Recent Exam 2013)
 - a. Duration not limited
 - b. Direction fixed
 - c. No latency
 - d. Vertigo not present
4. Spontaneous pure vertical nystagmus is seen in the lesion of: (Recent Exam 2017)
 - a. Medulla
 - b. Labyrinth
 - c. Middle ear
 - d. Cochlea
5. Destruction of right labyrinth causes nystagmus to:
 - a. Right side
 - b. Left side
 - c. Pendular nystagmus
 - d. No nystagmus
6. Stimulation of posterior semicircular canal produces: (Recent Exam 2013)
 - a. Horizontal nystagmus
 - b. Pure vertical nystagmus
 - c. Pendular nystagmus
 - d. Torsional vertical nystagmus
7. Vertigo of peripheral vestibular origin are all, except: (Recent Exam 2013)
 - a. Meniere's disease
 - b. BPPV
 - c. Vertebrobasilar insufficiency
 - d. Vestibular neuronitis
8. Vestibular function is tested by:
 - a. Galvanic stimulation test
 - b. Acoustic reflex
 - c. Fistula test
 - d. Impedance audiometry
 - e. Cold caloric test
9. Cold caloric test stimulates:
 - a. Cochlea
 - b. Lateral semicircular canal
 - c. Posterior semicircular canal
 - d. All of the above
10. At what angle is Hallpike thermal caloric test done: (Recent Exam 2016)
 - a. 15°
 - b. 30°
 - c. 45°
 - d. 60°
11. Fitzgerald's caloric test uses temperature at: (Recent Exam 2016)
 - a. 30° and 44°
 - b. 34° and 41°
 - c. 33° and 21°
 - d. 37° and 41°
12. Caloric test has: (Recent Exam 2016)
 - a. Slow component only
 - b. Fast component only
 - c. Both slow and fast components
 - d. Mainly slow component and fast component occasionally
13. In cold caloric stimulation test, the cold water induces movement of the eyeball in the following direction: (Recent Exam 2013, 2018)
 - a. Toward the opposite side
 - b. Toward the same side
 - c. Upwards
 - d. None of the above
14. If cold water caloric test is done in both the meatus simultaneously, the nystagmus will be: (Recent Exam 2012)
 - a. Vertical upbeat with slow component downward
 - b. Vertical downbeat with slow component upward
 - c. Horizontal to right
 - d. No nystagmus
15. Dunda's grant apparatus is used in: (Recent Exam 2017)
 - a. Cold air caloric test
 - b. Fitzgerald Hallpike's test
 - c. Bithermal caloric test
 - d. Rinne test
16. Fistula test following fenestration operation stimulates: (Recent Exam 2017)
 - a. Lateral semicircular canal
 - b. Posterior semicircular canal
 - c. Anterior semicircular canal
 - d. Cochlea
17. False positive fistula test is associated with: (Recent Exam 2017)
 - a. Perilymph fistula
 - b. Malignant sclerosis
 - c. Hypermobility of foot plate of stapes
 - d. Cholesteatoma
18. Hennebert's sign is a false positive fistula test when there is no evidence of middle ear disease causing fistula, it is seen in: (Recent Exam 2016)
 - a. Congenital syphilis
 - b. Stapedectomy
 - c. Fenestration surgery
 - d. Cholesteatoma
19. A positive fistula test during Siegelization indicates: (AIIMS 95, Recent Exam 2017)
 - a. Ossicular discontinuity
 - b. Erosion of lateral semicircular canal
 - c. CSF leak through the ear
 - d. Fixation of stapes bone
20. On otological examination all of the following will have positive fistula test, except: (Recent Exam 2017)
 - a. Dead ear
 - b. Labyrinthine fistula
 - c. Hypermobility of stapes footplate
 - d. Following fenestration surgery

21. Positional vertigo is due to stimulation of:

- Lateral semicircular canal (Recent Exam 2016)
- Superior semicircular canal
- Inferior semicircular canal
- Posterior semicircular canal

22. DIX-Hallpike maneuver is done for assessing:

(Recent Exam 2002)

- Vestibular function
- Corneal test
- Cochlear function
- Audiometry

23. What is the treatment for benign positional vertigo?

(Recent Exam 2018)

- Vestibular exercises
- Vestibular sedatives
- Antihistamines
- Canalith repositioning procedure

24. Latest treatment in BPPV is:

(Recent Exam 2018)

- Intralabyrinthine streptomycin
- Intralabyrinthine steroids
- Valsalva maneuver
- Epley's maneuver

25. Vestibular Evoked Myogenic Potential (VEMP) in sternocleidomastoid muscle detects lesion of: (AIIMS 2019)

- Cochlear nerve
- Superior vestibular nerve
- Inferior vestibular nerve
- Inflammatory myopathy

26. True about Hennebert's Sign is:

(Recent Exam 2016)

- Fistula test positive without fistula
- Fistula test positive with fistula
- Fistula test negative without fistula
- Fistula test negative with fistula

27. Dix Hallpike maneuver is used to:

(Recent Exam 2016)

- Diagnose benign paroxysmal positional vertigo
- Differentiate cochlear and retrocochlear deafness
- Assess neonatal hearing loss
- Assess patency of Eustachian tube

28. A person has vertigo without central involvement. Causes can be all, except: (Recent Exam 2016)

- Perilymph fistula
- Vestibular neuritis
- Meniere's disease
- Multiple sclerosis

29. Destruction of one semicircular canal leads to:

(Recent Exam 2016)

- Ataxia and dysarthria
- Spinning of world around sensation
- Cranial nerve VI deficit
- None of the above

30. What is being done in the following image?

- Syringing of the ear in a patient with CSOM and meningitis
- Testing vestibulo-ocular reflex by injecting cold water
- Politzerization (ventilation of the middle ear in children who cannot perform Valsalva maneuver)
- Determining Eustachian tube patency

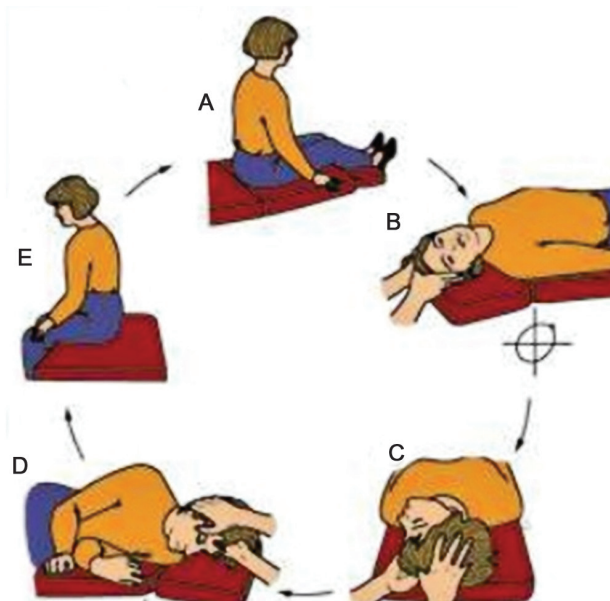
31. Not true about benign paroxysmal positional vertigo:

(Recent Exam 2016)

- Hearing loss is often present
- Hallpike maneuver is helpful in diagnosis
- Epley's maneuver is used for treatment
- Disorder of posterior semicircular canal

Image-based Practice Questions by the Author**32. The following procedure is done for the management of:**

(Recent Exam 2016, 2019)



- Meniere's disease
- Perilymph fistula
- BPPV
- Superior semicircular canal dehiscence

33. Positive head impulse test is suggestive of:

(Recent Exam 2016)

- Injury to SCC and vestibulo-cerebellar tract
- Injury to SCC and vestibulo-spinal tract
- Injury to SCC and vestibulo-ocular tract
- Injury to organ of corti and auditory pathways

34. When a patient was administered cold water in the right ear, the nystagmus was seen toward the left. Which of the following is the correct interpretation of the test?

(Recent Exam 2018)

- Fast component is to left
- Slow component is to left
- Disease is toward the left
- Direction of the nystagmus is to the right

35. While performing a caloric test, what type of nystagmus would you expect on doing a cold water irrigation?

(AIIMS 2018)

- Horizontal nystagmus toward the same side
- Vertical nystagmus toward the same side
- Horizontal nystagmus toward the opposite side
- Vertical nystagmus toward the opposite side

ANSWERS WITH EXPLANATIONS

1. Ans. (a) **Dix Hallpike maneuver**

2. Ans. (a) **Duration not limited**

(Ref. Cummings, 6th ed., page 2567; 2551)

3. Ans. (b) **Direction fixed**

(Ref. Anirban Biswas, 5th ed., Vol 2; page 98)

4. Ans. (a) **Medulla**

(Ref. Cummings, 6th ed., page 2531)

5. Ans. (b) **Left side**

(Ref. Anirban Biswas, 5th ed., Vol 2; 287)

6. Ans. (d) **Torsional vertical nystagmus**

(Ref. Cummings, 6th ed., page 2531; Scott Brown, 8th ed., Vol 2; page 833)

7. Ans. (c) **Vertebrobasilar insufficiency**

(Ref. Cummings, 6th ed., page 2531)

- Vertebrobasilar insufficiency is a central vestibular condition.
- The two vertebral arteries on each side are branches of the subclavian arteries. They enter the skull through the foramen magnum and join at the pontomedullary junction to form the basilar artery which divides into two posterior cerebral arteries at the upper pons.
- The vertebrobasilar arterial system perfuses the medulla, cerebellum, pons, midbrain, thalamus, and occipital cortex.
- Therefore, vertebrobasilar insufficiency leads to involvement of the central vestibular system.

8. Ans. (a) **Galvanic stimulation test; (c) Fistula test; (e) Cold caloric test**

(Ref. Scott Brown, 8th ed., Vol 2; page 795)

- Acoustic reflex and Impedance audiometry are tests of hearing.

9. Ans. (b) **Lateral semicircular canal**

(Ref. Cummings, 6th ed., page 2537)

10. Ans. (b) **30°**

(Ref. Cummings, 6th ed., page 2537)

11. Ans. (a) **30° and 44°**

(Ref. Cummings, 6th ed., page 2538)

12. Ans. (c) **Both slow and fast components**

(Ref. Cummings, 6th ed., page 2510)

13. Ans. (a) **Toward the opposite side**

(Ref. Cummings, 6th ed., page 2510)

- In bi-thermal caloric test, the normal response is C O W S, i.e., with Cold water nystagmus is toward the Opposite side and with Warm water it is toward the Same side.
- If both meatus are irrigated simultaneously with cold water, the normal response is an upbeating nystagmus with torsion.

14. Ans. (a) **Vertical upbeat with slow component downwards**

(Ref. Scott Brown, 6th ed., Vol 2; page 2/21/20)

- If both meatuses are irrigated simultaneously with cold water, under normal circumstances the effect within both horizontal semicircular canals is equal and self-cancelling; this eventually causes an upbeating vertical nystagmus.
- Vertical upbeat means the fast component is upwards, hence the slow component will be downwards.

15. Ans. (a) **Cold air caloric test**

(Ref. Dhingra, 6th ed., page page 43)

16. Ans. (a) **Lateral semicircular canal**

(Ref. Shambaugh, 6th ed., page page 466)

17. Ans. (c) **Hypermobility of footplate of stapes**

(Ref. Cummings, 6th ed., page 2562)

18. Ans. (a) **Congenital syphilis**

(Ref. Cummings, 6th ed., page 2562)

19. Ans. (b) **Erosion of lateral semicircular canal**

(Ref. Shambaugh, 6th ed., page 181)

20. Ans. (a) **Dead ear**

(Ref. Shambaugh, 6th ed., page 181)

- If there is a fistula on the medial wall but inner ear is dead (not responding to pressure changes), then in spite of presence of fistula, fistula test will be negative. This is false negative fistula test.
- If the footplate of stapes is hypermobile, it results in false positive fistula test.
- Fenestration operation is an iatrogenic cause of positive fistula test.

21. Ans. (d) **Posterior semicircular canal**

(Ref. Cummings, 6th ed., page 2550)

22. Ans. (a) **Vestibular function**

(Ref. Cummings, 6th ed., page 2551)

- DIX-Hallpike maneuver is a maneuver to rule out BPPV (benign paroxysmal positional vertigo) in any patient presenting with vertigo.

23. Ans. (d) Canalith repositioning procedure

(Ref. Cummings, 6th ed., page 2552)

- Canalith repositioning procedure or the Epley's maneuver is the treatment for benign positional vertigo. In this maneuver, the patient's head is moved into different positions in a sequence that will move the debris from the posterior semicircular canal back into the utricle.

- When the vestibular organs are damaged with disease or injury, the brain can no longer rely on them for accurate information about equilibrium and motion.

Vestibular exercises promote CNS compensation for these permanent or fixed deficits.

- In Benign positional vertigo, vestibular exercises are not required, as the cause of BPPV gets treated by Canalith repositioning procedure or the Epley's maneuver.
- Vestibular sedatives and antihistamines may be used to control the severe symptoms, though they are not of much benefit and repositioning or Epley's maneuver is the treatment of choice in BPPV.

24. Ans. (d) Epley's maneuver or the repositioning maneuver

(Ref. Cummings, 6th ed., page 2552)

25. Ans. (c) Inferior Vestibular Nerve

(Ref. Scott Brown, 8th ed., Vol 2; page 829)

26. Ans. (a) Fistula test positive without fistula

(Ref. Shambaugh, 6th ed., page 181)

27. Ans. (a) Diagnose benign paroxysmal positional vertigo

(Ref. Scott Brown, 8th ed., Vol 2; page 833)

28. Ans. (d) Multiple sclerosis

(Ref. Scott Brown, 8th ed., Vol 2; page 833)

29. Ans. (b) Spinning of world around sensation

(Ref. Scott Brown, 8th ed., Vol 2; page 774)

- Cerebellar pathologies present with ataxia and dysarthria
- Central causes of vertigo lead to deficits of cranial nerves III to XII which are closely associated with the brainstem.

30. Ans. (b) Testing vestibulo-ocular reflex by injecting cold water

(Ref. Scott Brown, 8th ed., Vol 2; page 795)

- Vestibulo-ocular reflex or caloric test is a test to evaluate the vestibular system and hence the brainstem functioning. One of the utility of this test is to confirm brain death.
- Syringing is never done in a patient of CSOM.
- Politzerization is for endotracheal tube function.

31. Ans. (a) Hearing loss is often present

(Ref. Cummings, 6th ed., page 2551)

32. Ans. (c) BPPV

(Ref. Scott Brown, 8th ed., Vol 2; page 835)

33. Ans. (c) Injury to SCC and Vestibulo-ocular tract

(Ref. Anirban Biswas, 5th ed., Vol 2; page 446)

34. Ans. (a) Fast component is to left

(Ref. Cummings, 6th ed., page 2510)

35. Ans. (c) Horizontal nystagmus toward the opposite side

ANSWERS OF CLINICAL CASE QUESTIONS

1. Ans. (d) The induced nystagmus disappears on removal of optic fixation

2. Ans. (a) 30° and 44°

3. Ans. (e) It will enhance on Optic fixation

4. Ans. (a) Assess vestibular function

5. Ans. (a) 2, (b) 1, (c) 3, (d) 4

6. Ans. (c) Direction of nystagmus will keep changing

7. Ans. (b) cVEMP will be absent or reduced in acoustic neuroma arising from the superior vestibular nerve