

Dialogue with Residents: Tuning Fork Tests

We will be discussing Tuning Fork Tests. To begin with let us learn about the Tuning Fork itself.

A tuning fork is produced by attaching a U shaped metal bar to a straight piece, termed the stem. The commonly used medical tuning fork-Gardiner –Brown has a disc like portion of the stem for the examiner to grip between the fingers, and an expansion, the foot piece which provides a suitable surface for the transmission of sound to skull. It also helps in application of the fork to the skull.

The limbs of the fork (tines) are termed prongs. The point where the prongs join the base is known as shoulder. The sides of the prongs which face one another are termed 'inner normal faces' and other sides which are parallel to these are termed 'outer parallel faces'.

When a force is applied to an outer normal face and right angles to it the prongs are set in transverse vibration and they alternately approach and separate from each other. The two nodal points which are situated in shoulders remain stationary and the intermodal segment vibrates in longitudinal axis of the prongs, this vibration is transmitted as longitudinal vibration to the stem.

If struck correctly the tuning fork produces a comparatively pure tone whose frequency is remarkably constant.

It is recommended that prongs should be struck at a point about one third of its length from the free end. By this means a pure tone is produced and overtones are kept at minimum. It is also recommended that tuning fork should be struck against some resistant but elastic object, for example a mass of rubber, thenar eminence or femoral condyle.

When testing hearing by air-conduction the fork should be held as close to the auricle as possible, without touching the protruding hair and such that the acoustic axis of the fork is coincident with the anatomic axis of the external acoustic meatus. The acoustic meatus corresponds to a line which is perpendicular to the normal faces of the fork and which passes through the point equidistant from both the free end and parallel faces of the corresponding fork.

As with any other instrument the tuning forks can also be calibrated. When a tuning fork has been calibrated capital letters A, B and C are engraved under the other on the base of the fork. Against each letter there is a number. These numbers specify the decay rate of the generated tone when the fork is used in the air-conduction (A) or bone conduction (B) mode. This number refers to the time in seconds which is required for the sound intensity to fall by 3 dB when sound is transmitted by air conduction or bone conduction mode. The intensity of sound produced by the tuning fork decays exponentially so that change in decibels is linear with the time.

The letter C refers to 'stem transmission factor'. This is defined as the number of half intensity periods for which the tuning fork could be heard by air conduction after hearing by bone conduction has ceased. A half intensity period is the time required for the sound intensity to fall by 3dB.

Let us understand it by an example: If a tuning fork is heard for 42 seconds by air conduction after it has been ceased to be heard by bone conduction and value for A (decay rate by air conduction) is 7 then the value for C is 6. Then the air conduction threshold calculated for that particular tuning fork frequency is $6 \times 3 = 18$ dB.

The tuning fork can be used not only qualitatively to determine type of hearing impairment but quantitatively also to measure the degree of hearing loss. In measuring the hearing loss, tuning forks can be accurate to within 10dB. It is recommended that when used to measure degree of hearing loss the sound should be applied intermittently, in the appropriate mode, for duration of one second, with three second interval. This would enable the clinician to reduce the effect of any auditory adaptation on the measurement of threshold.

Hopefully the examiners have essentially normal hearing and can compare the patient's hearing with their own hearing to obtain a measure of the hearing loss. By means of A and B values on the fork the time difference between the patient's end-point of hearing and those of examiner can be converted to hearing levels in decibels for both air and bone conducted sound.

You may find it bit difficult to understand, but the concept will crystalize when we will discuss individual tests...

Rinne (or Polansky-Rinne) Test

This is the best known test of the tuning-fork tests used to distinguish conductive from sensorineural hearing loss.

In the Rinne Test, the patient's ability to hear by bone conduction is compared with that by air conduction.

The clinician can simply ask 'which is louder, number one sound' (holding the vibrating fork with prongs near the ear)' or 'number two sound?' (transferring the same vibrating tuning-fork to press the footpiece gently but firmly on the corresponding mastoid process)

- A normally hearing subject will say 'Number one sound'; or so will a subject with a sensorineural hearing loss, unless the loss is marked.
- A subject with an incipient conductive loss or with a conductive component up to 20 dB in a mixed loss will also give the same response.
- The response in which a sound is heard better by air conduction than by bone conduction is referred to as a Rinne Positive response.

If a tuning-fork is heard better by bone conduction than by air conduction then test is termed as 'Rinne negative response'.

- Such cases may be due either to bone conduction sounds being heard in the opposite ear (in cases of severe or total hearing loss in the tested ear)
- Or an appreciable impairment of sound transmission in the affected ear, that is conductive hearing loss in that ear in excess of 15-20 dB hearing level

The two conditions can be differentiated by applying a Barany's noise box to the opposite ear. This masking noise raises the threshold of hearing in the non-tested ear to such a level that tuning fork cannot be heard in that ear by cross hearing.

Thus if the Rinne Test is repeated with noise applied to the opposite ear and this abolishes the hearing by bone conduction in the test ear the Rinne response is said to be false negative Rinne response.

If the Rinne negative response (bone conduction better than air conduction) is still obtained with a noise box applied to the opposite ear, then the result is said to be true negative Rinne response.

Repetition of the test with contralateral masking is still required in bilateral Rinne Negative responses, since such a result may be found in a patient with a pure conductive loss on one side and total sensorineural hearing loss on the other side.

Responses of a subject indicating a bilateral false negative Rinne response indicate a non-organic hearing loss.

In a patient with a unilateral hearing loss showing a negative Rinne response, the direction of lateralisation of weber test would indicate to the examiner the nature of hearing loss (however repetition of test with contralateral masking is recommended)

A number of factors which may account for varying results are:

- Placement of the foot piece should be over suprimeatal triangle.
- Whether or not fork touches the auricle.
- Force of application of tuning-fork
- Force with which the fork is excited.

The sensitivity of the Rinne test can be improved and quantification provided by following Bezold's suggestion of measuring the time which elapses between cessation of bone conduction excitation and cessation of air conduction excitation.

For example If A value of the particular tuning fork used is 4, and the C value 6, then a normally hearing person would be expected to hear the fork by air conduction for :

$A \times C = 4 \times 6 = 24$ seconds after it has become inaudible by bone conduction. This period of time would correspond to a fall in the sound intensity of , $3 C = 18$ dB

A hearing impaired person who is able to hear the fork for t seconds by air conduction after ceasing to hear it by bone conduction will have a conduction loss given by following equation:

$$H_c = 3 (C-t/A) \text{ dB}$$

Where H_c is the conductive hearing loss in dB

A is decay rate of the tuning fork in air conduction mode expressed as the time required for a fall in intensity of 3 dB and C is the characteristic of the fork.

Similarly there is a method to calculate hearing loss in a patient with Rinne negative response.

The Schwabach test

The Schwabach test is a measure of the threshold of hearing by bone conduction of an unoccluded ear (relative bone conduction). It is thus the clinical equivalent of what is done in bone conduction audiometry.

The test compares the patient's ability to hear a tuning fork by bone conduction with that of a normally hearing person.

The test is usually done by placing the footpiece of a vibrating tuning fork on patient's mastoid process and asking the patient to say when the tuning fork is no longer heard. As soon as he/she indicates that this point has been reached the footpiece of the tuning fork is transferred to the mastoid process of a normally hearing person. (Usually the examiners consider their hearing to be normal so compare the patient's hearing with their own hearing by bone conduction)

If the observer can hear the tuning fork after the patient has ceased to hear it, the Schwabach test is considered 'shortened'. This is the finding in sensorineural hearing loss.

If the examiner cannot hear the tuning fork immediately after it has been transferred to his or her mastoid process, the sequence is reversed. One then determines for how long the patient can hear the tuning after it has been ceased being heard by the examiner. Such results may be obtained in conductive hearing loss.

Because of the absence of any appreciable interaural attenuation for bone conduction sound, the test should be repeated with a Barany noise box applied to the non-tested ear. This will mask that ear and ensure that, at least for low frequency tuning forks the Schwabach test measures the bone conduction levels of the ear under test.

The mechanism of bone conduction is complex. However, the 'prolonged' Schwabach response on conductive hearing loss is primarily due to exclusion of masking effects of ambient noise which applies to usual test conditions.

The bone conduction hearing level of the corresponding ear can be calculated by converting the time difference between the two thresholds (that of the patient and the examiner) to a value in decibels using the B calibration on the tuning fork.

In order to minimize the adaptation effects it is recommended that tuning fork be applied intermittently.

Pomeroy's Test or Absolute Bone Conduction Test

Pomeroy's test is a measure of the threshold of hearing by bone conduction of the occluded ear (absolute bone conduction)

This test is performed in the same manner as Schwabach Test except that the examiner applies firm pressure on the tragus of the ear being tested. The effect is thus standardized by 'giving everybody a conductive hearing loss' and excluding the masking effects of the usual ambient clinic noise.

Because of this attenuation of the room masking noise and the operation of occlusion effect, the Pomeroy's test will normally give lower, that is better thresholds than the Schwabach test.

Patients with conductive hearing loss will show either a reduced difference between thresholds determined by two tests or identical thresholds.

Like the Schwabach test, 'a shortened Pomeroy Test' is indicative of a sensorineural component.

Pomeroy's test may also be performed as an audiometric procedure.

It is recommended that both absolute and relative bone conduction thresholds should be measured. The variability in results of Pomeroy's test may arise from differences in the pressure used to occlude meatus as well as those used in applying the tuning fork footpiece to the mastoid process.

Bing Test:

In this tuning fork test occluded and unoccluded bone-conduction thresholds in the same subject are compared.

The phenomena of whereby a bone-conducted sound is perceived to be louder in when ipsilateral meatus is occluded is due to elimination of normal high-pass filter effect produced by unoccluded external acoustic meatus. (Resonant peaks occur in an unoccluded ear canal in the vicinity of 3000Hz and these peaks diminish when the ear canal is occluded)

The test may be performed by either a loudness comparison method or by a threshold comparison method. In either case, the footpiece of a vibrating fork is applied to the mastoid process. After ensuring that the patient hears it, the corresponding external acoustic meatus is occluded by pressing a fingertip on the tragus.

The patient is then asked: 'Does that make the sound quieter, louder or no change?' If the subject says that sound becomes louder, the bing test is said to be positive; other responses are termed negative Bing responses.

An increase in loudness after occlusion after occlusion of meatus occurs with normal sound-conducting mechanism.

Defective sound-conducting mechanisms, that is those producing conductive hearing losses, are associated with negative Bing responses.

With the threshold method, the tuning fork is intermittently applied to the mastoid process until it is no longer heard. The ipsilateral meatus is then occluded by pressure on the tragus. Then patient is asked whether or not anything can be heard.

It has been found that using the loudness comparison method this test can detect conductive hearing losses of 9dB or more.

Some scientists believe that Bing test is more valuable than Rinne Test in differentiating between a conductive and a sensorineural hearing loss.

The preferred frequency for the tuning fork for both the Bing and Rinne test is 256Hz.

Wollaston's Test

Wollaston reported that some hearing impairment patients have a hearing loss which is predominantly low frequency; others have a predominantly high frequency hearing loss. Moreover he showed that these frequency impairments were correlated with conductive and sensorineural hearing losses, respectively.

This is a good generalization. But there are some exceptions:

- Endolymphatic hydrops is a low-frequency sensorineural hearing loss
- An ossicular chain disruption may give rise to high frequency conductive hearing loss.