CHAPTER 2.

HEARING AND BALANCE TESTING

1. HEARING TESTS (AUDIOLOGY)

Audiology assists in the differentiation of a wide range of hearing impairment situations. A considerable variety of assessments are available to ascertain the nature of the hearing loss and also to identify the site and appropriate management. The tests cover both the perception of sound itself, and also the transmission of these effects to and into the brain itself, plus other aspects relevant to disease and its treatment. The tests are increasingly performed by personnel with advanced technological expertise, as the demands of the complexity of the assessments increases.

a) Pure Tone Audiology (PTA)

This test is perhaps the most venerable of modern day hearing assessments, yet remains the most valuable of the otologist’s audiological armamentarium. The PTA assesses hearing acuity by providing a graph of the loudness thresholds (the hearing level at which sound can just be heard) measures across a range of frequencies (250 cps to 8000 cps). Two assessments are performed at each frequency. The graph produced (audiogram) is achieved by testing with headphones in a soundproof environment.

![Figure 1: Normal pure tone audiometry. In children the levels are often between five and ten decibels, but 15-20db in the elderly.](image)

Initially “air conduction” (AC) is measured for each frequency. This is the normal sound heard by the ear, the results being plotted across the frequencies tested. The patient signals when the sound is delivered, the threshold being set at the point of no response.

Next the “bone conduction” (BC) is measured. A vibrator is placed firmly on the mastoid, which vibrates the skull, stimulating the cochlear hair cells. The audiological power is calibrated according to the ability of the perfectly hearing ear to detect the bone conduction sound. The bone conduction thresholds are measured in similar fashion to the air conduction tests, but only over 500, and 1000, 2000, 3000, and 4000 cps. Perfect hearing for both tests is set at zero decibels.
In purely conductive (mechanical) losses, due to external or middle ear impediment, the BC level remains excellent at zero, but the actual AC hearing threshold is less: the gap between the levels on the resultant audiogram is the clearly demonstrated conductive loss.

The BC levels fall, and with them the AC results, as the latter cannot exceed the hearing of the cochlear hearing ability, as depressed by the nerve dysfunction. Sensorineural losses are therefore characterised by identically depressed AC and BC outcomes.

In other cases, conductive deafness and also sensorineural losses co-exist causing “mixed deafness” with depressed BC levels, but with worse AC results.

**Figure 2:** Left conductive deafness. The air conduction in the left side is depressed to 60db whilst the right air conduction and the bone conduction levels remain normal. The “air-bone gap” between the left air and bone conduction levels represents the conductive deafness.

If the external and middle ears are functionally normal, but the nerve performance has declined, sensorineural deafness is present.

**Figure 3:** Right high frequency sensorineural deafness, showing decline in both the air and bone conduction levels.

Generally, conductive deafness has a low frequency character, although high frequency conductive losses co-exist with the lower in severe cases. Conductive losses confined to the high frequencies usually indicate aberrant audiological assessment, the BC levels at 3000 and 4000 being notoriously subject to variation. Sensorineural losses usually have high frequency preponderance. Purely low frequency sensorineural losses are unusual, normally associated with specific conditions.

**Figure 4:** Mixed deafness. A conductive loss with an air-bone gap of 50 db in the lower frequencies, combined with high frequency bone conduction losses. The pattern is one seen in the elderly with conductive losses, or when a chronic middle ear infection is complicated by low grade ototoxic effects.
b) Computerised Audiology

The digital age ushered in a range of tests of nerve function that discern the neural responses of the cochlea and its CNS connections that are detectable only with computerised facilities.

(i) Auditory Brainstem Response assessments follow the sequences of responses from the cochlea to the brain. They are used to check for retrocochlear disease, and are also widely used for newborn infant screening, when the child is too immature for pure tone assessments. The test is also useful for non-organic deafness.

(ii) Electrocochleography assesses the action of the cochlear hair cells. This is useful in deafened ears when the site of lesion is uncertain, e.g. after meningitis or auditory dyssynchrony.

The pressure in the external canal can be varied by the pressure pump (p).

l: loudspeaker, m: microphone.

Tympanometry assesses the elasticity (compliance) of the tympanic membrane by means of a low frequency sonar probe. When sound from the probe strikes the drum, part of the sound is absorbed and part reflected. Absorption is maximal when the drum is least taut, i.e. when the pressure within the middle ear equals the atmospheric outside. If pressure changes inside the ear place the drum under tension, more sound is reflected. The tympanometer probe is therefore equipped with an emitting source and a microphone. In addition, an airtight seal and pump provide variable pressure in the external meatus (form +400 mm H₂O to -400 mm), which is continually monitored.

i. Eustachian Insufficiency

Figure 5: Principles of tympanometry. Sound is directed at the tympanic membrane. Part is absorbed and part is reflected back to the probe.

Figure 6: Type A tympanometry curve. Normal middle ear pressure. The compliance curve peaks when the external canal pressure equals the middle ear pressure at atmospheric pressure.

The pressure of the external canal at which the compliance becomes maximal can be recorded; this will be the pressure of the middle ear, as the compliance is maximal when the pressures are equal. In normal ears a Type A curve is recorded, maximal when middle ear pressure equals the external atmospheric pressure.
Figure 7: **Type B** tympanometry curve. Middle ear effusion. The compliance of the tympanic membrane varies little due to the inflexible nature of the middle ear fluid.

If fluid is present in the middle ear, however, the compliance remains unchanged, recorded as a flat Type B curve, as the drum is “splinted” by the incompressible liquid.

By these measurements, however, it can also be deduced if a partial vacuum is present due to tubal insufficiency. Here the peak will shift into the negative zone as the middle ear pressure is less than the external: Type C curves

Figure 8: **Type C** tympanometry curve. Tubal insufficiency causing a negative middle ear pressure. Compliance peaks when the external canal pressure is adjusted to match the negative middle ear pressure, here at -300mm.

Not uncommonly, the test may give aberrant type B results. This occurs from a variety of causes: the canal may be blocked with debris; the drum may be stiff from tympanosclerosis or perforated; the probe may be misdirected.

Figure 9: Aetiology of **false Type B** tympanometry results. 1: Misdirected sound problem; 2: EAC debris; 3: Perforated drum; 4. Hardened drum (e.g. tympanosclerosis.

ii. Reflex testing

When the ears are simulated with loud sound (80-90db), the stapedius muscle contracts; this can be measured by tympanometry. The contralateral muscle will also be activated. Louder sound will be required if conductive deafness is present.

These tests are useful to routinely check children’s hearing. Also, if a facial palsy originates medial to the branch to the stapedius, the reflex will be lost. The reflexes may also be diminished by retrocochlear disease.
2. BALANCE ASSESSMENTS

a) Electronystagmography / Vestibulonystagmography (ENG, VNG)

Abnormal vestibular function results in flicking of the eyes (nystagmus). This phenomenon can be detected by electrodes placed near the eyes, as the cornea is positively charged compared with the retina. Thus movements may be induced, studied, and measured as hard data for future reference.

i. Gaze testing
Change of direction of nystagmus with change of the direction of the patient’s eyes is suggestive of a CNS lesion. Vertical nystagmus also results from these origins.

ii. Optic fixation
Nystagmus from vestibular origins may be reduced or abolished by the eye fixing on a given point. This is readily noted on ENG, and may be abolished by taping the eyes.

iii. Neck positioning
In some cases nystagmus may be induced by changes in neck position that induce vascular ischaemia due to arterial compression in the cervical spine.

i. Fistula test
If a labyrinthine fistula or other abnormal defects of the otic capsule are present, pressure applied within the external canal may produce noticeable nystagmus, noted on ENG

b) Caloric testing
ENG testing is accompanied by stimulating the lateral semicircular canals with warm ($44^\circ$) or cool ($30^\circ$) water or air. Under standard conditions, this produces measurable nystagmus. The response of each ear can be assessed for weakness due to ear or VIII disease. Hyper-responsiveness may indicate cerebellar disease.

c) VEMP test
(Vestibular evoked myogenic potential). When stimulated with a loud “click” the saccule has a mild muscular relaxation effect on the sterno-mastoid muscle. Abnormal relaxation responses may indicate a saccular disorder or conditions such dehiscent superior semicircular canal.