OPEN ACCESS GUIDE TO AUDIOLOGY AND HEARING AIDS FOR OTOLARYNGOLOGISTS

CLINICAL ASSESSMENT OF HEARING: FREE FIELD VOICE TESTING & TUNING FORKS

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This chapter deals with clinical assessment of hearing which often follows taking at least a partial history and otoscopy, and is generally supplemented by audiometry.

Clinical assessment of a patient with otologic symptoms has three interrelated components *i.e.* history, otoscopy and assessment of hearing. Sometimes examination of the nose, postnasal space and balance is also indicated.

The literature relating to clinical hearing assessment is based primarily on adults but is also applicable to older children. Modifications to the techniques of assessment in a paediatric population are made where relevant.

History

In medicine, history taking can be helpful in several ways including:

- Help to diagnose a disease
- Assess the patient's symptoms and consequent disability
- Informally assess the likely degree of overall hearing disability by noting patients' responses to questions

Because of our ability to diagnose the majority of external and middle ear conditions by otoscopy, the history is often of little additional value in reaching a diagnosis. Thus in a patient with otoscopic evidence of chronic otitis media, the object of taking a history is not to make the diagnosis but to assess the resultant disability and to plan management. Equally, if an audiogram is available when a patient is seen, history taking is very different in those with sensorineural as opposed to conductive impairments. The temptation then is not to carry out the clinical assessment in the traditional order of history followed by examination. Indeed, the order of partial history, followed by otoscopy and clinical assessment of hearing, including audiometry, followed by further history has much to commend it.

History in Disability Assessment

The fact that a symptom is present does not mean that all patients have a similar disability. This is particularly obvious in patients with a hearing impairment where the degree and symmetry of the loss, along with the patient's lifestyle and motivation, combine to produce different degrees of disability. With symptoms such as ear discharge the factors which contribute to disability are less recognised, but psychosocial factors have a considerable impact. A fuller discussion of how to assess hearing disability is beyond the scope of this chapter but it is important to realise that ***disability is usually what determines management rather than symptoms per se***.

Otoscopy

How to perform otoscopy and interpret the findings is discussed in the open access chapter on *otoscopy and video-otoscopy* (in preparation). Thus, a young adult with hearing impairment is more likely to have chronic otitis media than sensorineural impairment, whilst an elderly patient is more likely to have sensorineural impairment than chronic otitis media, though he/she may have both. What can be said is that the presence of pathology of the tympanic membrane and middle ear will inevitably affect the conductive hearing mechanism. It is mandatory to remove wax to visualise the tympanic membrane if there is a conductive impairment so that an otoscopic diagnosis and clinical assessment of the hearing can be made. The exception is children in whom otitis media with effusion is likely. In this situation tympanometry can be of diagnostic value and can be carried out in the presence of wax [1]. Tympanometry with bilateral type B or C2 tympanograms has 96% sensitivity and 42% specificity in predicting hearing loss of 25 dB HL or poorer in the better hearing ear of children with suspected otitis media with effusion. Care has to be exercised to ensure that a congenital sensorineural loss is not missed.

Clinical Masking of Hearing

With clinical testing of hearing it is ***important to mask out hearing in the non-test ear***. The rules and methods involved are different from those in audiometry.

Masking Air Conduction

Sound arriving at the ear on one side via air will also be heard by the ear on the other side, but because of the head shadow will be attenuated by an amount depending on the frequency (*Table 1*).

	Frequency (kHz)						
	0.25	**0.5**	**1**	**2**	**3**	**4**	**8**
Mean	1	1	1	7	10	13	10
Maximum	2	4	5	11	15	18	15
Minimum	0	0	0	5	9	10	5

Table 1: Amount (dB) the head shadow attenuates sound coming via air from the contralateral ear (After Shaw, 1974)

As the minimum attenuation at the lower frequencies is 0 dB and as it is wiser to rather mask unnecessarily than to omit masking when necessary, the rule is that ***the non-test ear should always be masked when clinically testing hearing by air conduction***. The same rule does not apply in audiometry.

Methods of masking air conduction

The two most commonly used methods are tragal rubbing and the Barany box. Unfortunately there is no single method that can produce the required range of masking levels required; so no one method is suitable for all situations *(Table 2)*.

Voice test	**Distance from patient**	**Masking method**
Whispered voice	60 cm	Tragal rubbing
Whispered voice	15cm	Tragal rubbing
Conversational voice	60 cm	Tragal rubbing
Conversational voice	15 cm	Tragal rubbing
Loud voice		Barany Box

Table 2: Appropriate method of masking the non-test ear when voice testing

For example, there will be occasions when tragal rubbing provides insufficient masking. On the other hand, in most circumstances a Barany box will produce too much masking and will mask the test ear as well as the non-test ear.

Tragal rubbing

Occluding the external auditory canal with a finger placed on the tragus only attenuates sounds by ~10dB and so is of no value. However if the tragus is rubbed at the same time as the canal is occluded, speech is attenuated by ~50dB *(Figure 1)*.

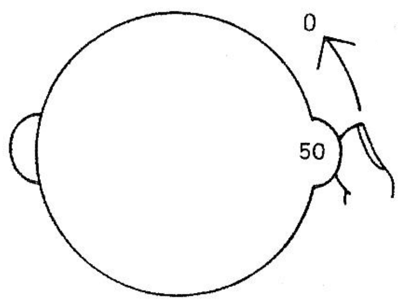

Figure 1: Speech attenuated by ~50dB when tragus is rubbed at the same time as the canal is occluded

The advantage of tragal rubbing over other methods is that the masking sound is produced within the external auditory canal and there is no risk of sound crossing over and masking the test ear. It also does not require any equipment. However, there is a danger of under-masking if the level of speech is >70 dB A. This means that a Barany box will be necessary when using a loud voice in free-field speech testing. Tragal rubbing will also be insufficient when using tuning forks in those with a severe or profound loss. However in these circumstances the tests are hard to interpret because it is difficult to activate the tuning forks sufficiently for them to be heard.

Barany box *(Figure 2)*

For many years the Barany noise-box was the standard method of clinical masking. It produces a broad-band noise, although there can be marked dips in the frequency spectrum of some boxes and the noise can be irregular.

Figure 2: Barany noise-box

The maximum sound output various from box to box but a lower limit of 90 dB A can be assumed when a box is held at right angles to the ear, and 100 dB A when held over the ear *(Figure 3)*. These levels are sufficient to mask one ear in all practical circumstances, but there is a danger that, because the sound can travel round the skull to the test ear, this will be masked as well *(Figure 4)*. Eighty percent of normal ears will be masked by a Barany box in the other ear as evidenced by the inability to detect a whispered voice at 2 feet. Because of this a Barany box should only be used in free-field speech testing when testing an ear with a severe or profound impairment, *i.e.* one that cannot hear a conversational voice at 6 inches.

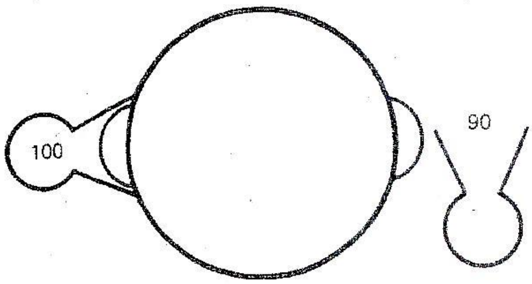

Figure 3: Sound outputs of Barany box

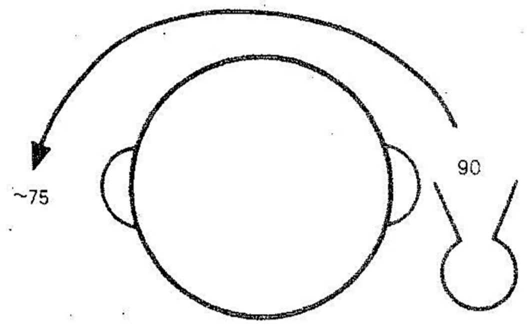

Figure 4: Risk of masking contralateral test ear

Masking Bone Conduction

With bone conduction the transcranial attenuation from one ear to the other is taken as zero *(Figure 5)*.

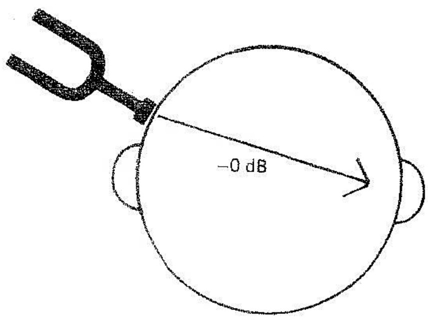

Figure 5: Zero dB interaural attenuation of transcranial bone conduction

So bone conduction should in theory always be masked when performing tuning fork tests; but in practice this can be difficult. A Barany box is necessary as tragal rubbing provides insufficient bone conduction masking when a conductive impairment is present in the ear being masked.

Free-field voice tests of hearing

It is remarkable how often clinicians omit to assess a patient's hearing by free-field voice testing. Rinne and Weber tuning fork assessments are often done with the aim to determine whether an impairment is conductive or sensorineural. ***How tuning fork tests can be interpreted in the absence of knowledge of the degree of impairment is a mystery***.

Value of free-field voice testing

Free-field voice testing ***can be used in two ways***:

1. ***As a screening method*** to detect whether a hearing impairment is present in one or both ears; only a ***whispered voice*** is used for screening
2. ***To determine the severity of an impairment*** that has been identified; this is achieved by assessing the hearing threshold for speech by ***varying the vocal effort and the distance*** from the test ear to produce a range of speech sound levels

Free-field voice testing takes only 1-2 minutes and although not as reliable as pure tone or speech audiometry, is of value for the following reasons:

- ***Audiometry may not be required:*** There are two common circumstances where audiometry may be dispensed with as a result of free-field voice testing. The 1st is where a previous audiogram is available and there has been no change in symptoms. The 2nd is where hearing screening is required. This may be in patients without otological symptoms such as the elderly, or in those who require reassurance that they have normal hearing

- ***To check audiometry***: Following otoscopy and free-field voice testing it should be possible to predict the type and severity of impairment in each ear. Comparison can then be made with the audiogram and where discrepancies arise, one or both must be incorrect. Exaggerating thresholds when claiming compensation for noise trauma is the commonest reason for both to be wrong. Another common reason is difficulty with audiometric masking; this occurs most frequently in those with conductive or asymmetric impairments where it is important to have accurate results.

How to do free-field voice testing

- Explain to the patient that he/she is expected to repeat back what he/she hears being said by the examiner as accurately as possible
- Stand behind the patient to eliminate speech reading and say a test word loudly enough to ensure that the task is understood
- Thereafter use combinations of numbers and letters *e.g.* 5B3 as this permits a large variety of combinations
- Bisyllabic words *e.g.* cowboy, football are often used for children. Reading from a list of options can make it easier for the less experienced tester to concentrate on the sound level of his/her voice
- Test the better hearing ear first if there is one
- Mask the non-test ear by tragal rubbing
- Masking can be omitted in children and the elderly when used as a screening test to assess whether there is a bilateral impairment worthy of investigating or managing

Free-field voice testing as a screen to detect a hearing impairment

When free field voice testing is used as a screening method the examiner uses a whispered voice 2 feet (60cm) away from the patient, which is the furthest one can reach from to mask the non-test ear. Provided a whisper is used, and this is best achieved by exhaling first, a patient who ***cannot repeat what is said in a whispered voice at arm's length is hearing impaired***, that is, would benefit from management such as amplification (pure tone average (PTA) ≥25 dB HL). If the patient ***can repeat back what is said in a whispered voice it does not actually mean that the hearing is normal***, as a normal hearing ear in a young adult will hear a whisper at least 12 feet (4 m) away. Rather it means that the likely associated disability is insufficient by itself to merit management.

Free-field voice testing to grade the severity of a hearing impairment

If a patient fails to hear a whispered voice at 2 feet (60 cm) the test can be extended by gradually increasing the loudness of the voice. The patient's ***free-field threshold is the voice and distance level at which he/she gets more than 50% correct***. So the relative sound level is increased in steps to a whispered voice at 6 inches (15 cm), to a conversational voice at 2 feet, to a conversational voice at 6 inches (15 cm), to a loud voice at 2 feet (60 cm) and finally to a loud voice at 6 inches (15 cm). The number and/or letter combinations should be changed for each new presentation to avoid the patient recognising them from previous presentations. The test is terminated when the patient repeats 50% of the words correctly at any one voice and distance level. When using a loud voice, a Barany box must be used as tragal rubbing provides insufficient masking. If there is any doubt concerning a threshold, the examiner can test again at a lower voice level.

Clinical voice tests have been criticised because of the lack of standardisation of sound levels of speech between examiners and because of the considerable difference in sound levels produced by an examiner on different occasions, particularly when whispering. To avoid this, whispering should be done after full expiration and with a list of numbers and letters to read from.

Despite these criticisms, monaural, free-field speech done by experienced oto-logists can reliably screen individuals for a hearing impairment greater than 25 dB HL and can grade the severity of hearing impairment into normal, mild/moderate and severe/profound [2]**.**

Method of free-field voice testing in children

In older children, bisyllabic words familiar to them such as 'cowboy' or 'football' can be used instead of numbers and/or letters. If this is thought to be impractical the children can be sat on their mothers' laps and facing them, a game of getting them to point to various parts of their body/clothes is started *e.g.* 'Point to your ……'. This can then be done after moving to behind the mother and using a whispered voice. No attempt is made to mask one ear; the better hearing ear is therefore being tested to determine whether there is an impairment, as this is what one is really wishing to establish at this stage of screening.

Interpretation of free-field voice testing

Screening for hearing impairments

Individuals with an average speech frequency >30 dB HL are unable to hear a whispered voice 2 feet from the test ear. The sensitivity ('hit rate') of this is 95% and the false-positive rate 10% (*Table 4).*

Impairment	Sensitivity	Specificity
PTA over 0.5, 1 & 2 kHz		
≤25 dB HL	86%	94%
≤30 dB HL	95%	90%
≤35 dB HL	100%	84%
PTA over 0.5, 1, 2 & 4 kHz		
≤25 dB HL	91%	96%
≤30 dB HL	96%	91%
≤35 dB HL	98%	86%

Table 4: Sensitivity and specificity of a hearing impairment being detected by an individual's inability to hear a whispered voice at 2 feet (After Browning et al, 1989)

Hence, if a patient can hear a whispered voice 2 feet from his ear the clinician can be fairly certain that the pure tone thresholds will be better than 30 dB HL; in many instances this makes an audiometric evaluation unnecessary.

Grading the severity of an impairment

A comparison of free-field thresholds and mean PTA over 0.5, 1, 2 and 4 kHz, along with the 5th and 95th percentiles is made in *Table 5*.

			PTA	
			Mean	**Percentiles**
Voice level	**Distance**	**(dB)**	**5th**	**95th**
Whisper	60 cm	12	-	27
	15 cm	34	20	47
Conversation	60 cm	48	38	60
	15 cm	56	48	67
Loud	60 cm	76	67	87

Table 5: Comparison of free-field voice thresholds and pure tone average (PTA) over 0.5, 1, 2 and 4 kHz (After Swan and Browning, 1985)

Though there is some overlap, patients can be divided into three groups by free-field voice testing; PTA <30 dB HL; PTA 30-70 dB HL; and PTA >70 dB HL; this corresponds to normal, mild/moderate and severe/profound impairments, respectively.

The Rinne test

The Rinne test is the most frequently used tuning fork test, its stated role being to identify a conductive defect. It is extremely helpful to have performed otoscopy because ***if there is evidence of middle ear pathology then the Rinne test is probably of no benefit***. What is required in such cases is an assessment of the magnitude of the conductive impairment; audiometry is the only way of doing this.

However in the presence of ***normal otoscopic findings*** the Rinne test has a role in terms of identifying those with a conductive hearing impairment due to ***otosclerosis***.

It is extremely helpful to have performed ***free-field voice testing prior to doing the Rinne test***, because knowledge of the degree of impairment and the symmetry between ears greatly aids interpretation. Thus if there is gross asymmetry, there is the possibility of a false-negative Rinne (see below). Knowledge of the degree of impairment is also of benefit in deciding how to mask. Thus a Barany box is necessary in a patient with a unilateral impairment.

Choice of tuning fork

Although forks of ***512 Hz are usually preferred***, there is evidence that ***256 Hz forks are more accurate***. A potential problem of using forks with a frequency <256 Hz is that patients may experience difficulty distinguishing between the sound and feeling the vibration. It is difficult to sufficiently activate forks with a frequency of > 512 Hz for them to be heard by those with a moderate or severe sensorineural impairment.

Tuning forks should be as ***heavy as possible as the sound level produced is***

more sustained. Though forks vary, a decay of 10 dB HL every 10 seconds is the slowest that can be anticipated. The sound level produced by light forks decays rapidly which is a disadvantage as there is inevitably a time delay between asking the patient to compare the loudness by air and bone conduction.

Method

The patient is asked to make a ***comparison between the relative loudness of the air and bone conduction***. Alternatively, the sound in one of the test modes can be allowed to ***decay*** until it is no longer heard and the patient is then asked if he/she can hear it by the other mode. In general, loudness comparison techniques identify smaller air-bone gaps than decay methods.

Activating a 512 Hz fork by compressing the tines between the fingers produces a sound level of ~70 dB SPL (sound pressure level) whereas hitting it against the knee or elbow without causing pain, produces a sound level of ~90 dB SPL.

The ***tines of the fork*** should be held directly in line with the external auditory canal when testing air conduction, as holding it at an angle diminishes the sound level.

The tuning fork must make ***good contact with the skull*** when testing bone conduction. This is not achievable on the mastoid tip; the best position is on the flat bone just superior and posterior to the external canal. It is important that ***firm pressure*** be applied because the sound level can vary by as much as 15 dB with different degrees of pressure. As the patient's head tends to move away from the tuning fork, it is best to steady the head by placing the examiner's free hand on the contralateral side of the head.

By convention the results are ***reported as Rinne positive*** when air conduction is louder than bone conduction and ***Rinne negative*** when bone conduction is louder than air conduction. Many clinicians, including the author, find it difficult to remember which is which, so reporting the results as to which route is louder bypasses this problem.

False-negative results

Because the bone conduction on the poorer hearing side may be heard by the better ear, this may result in a false-negative Rinne. It is therefore theoretically important to mask the non-test ear whenever the bone conduction is being tested, particularly when testing the poorer hearing ear.

The only way to mask bone conduction is by making a sound at the external auditory meatus of the non-test ear. However if there is a hearing impairment in the non-test ear, tragal rubbing and even a Barany box may be insufficiently loud *(Figures 1-3)*. On the other hand, if a Barany box was used routinely there would be a considerable danger of masking the bone conduction in the test ear as well *(Figure 4)*.

Knowledge of the degree of impairment by free-field voice testing helps determine which method to use, but even then there is often some uncertainty. Consequently many otologists omit to mask tuning fork tests unless there is gross hearing asymmetry.

Validity

It is generally held that the Rinne test will reliably detect a conductive defect of 20 dB or greater…. This is not so! This is the level at which 50% of patients with an air-bone gap of 20 dB will be Rinne positive and 50% will be Rinne negative.

The value of the Rinne test is best evaluated on data which has analysed the proportion of ears with different sizes of air-bone gap which are Rinne positive and negative. The false-negative and false-positive diagnosis rates can then be calculated for each size of air-bone gap. An example of such an analysis is shown in *Figure 5*.

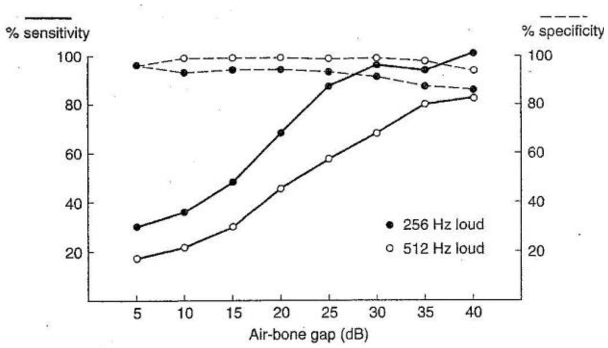

Figure 5: Sensitivity and specificity of 256 Hz (●) *and 512 Hz* (o) *tuning forks in detecting differences in air and bone conduction of various magnitudes (after Browning et al. 1989)*

From this and other studies it is possible to calculate *(Table* 6*)* the size of air-bone gap that will be correctly identified 50, 75 and 90% of the time, the first value being included being the size of air-bone gap that would be correctly detected at the same level by tossing a coin.

	Confidence limits		
	50%	**75%**	**>90%**
256 Hz fork:			
Crowley & Kaufmann (1966)	25dB		30dB
Gelfand (1977)		40dB	
512 Hz fork:			
Crowley & Kaufmann (1966)	25dB		30dB
Wilson & Woods (1975)			40dB
Gelfand (1977)		40dB	
Golabek & Stephens (1979)	19dB		
Browning and Swan (1988)	20dB		45dB

Table 6: Size of air-bone gap (dB) which would be correctly identified by Rinne test on various percentages of occasions

Though each of the studies can be criticised in different ways, ***the overall conclusion is inescapable; that the Rinne test will not reliably detect, i.e. in 90% of tests, a conduction defect unless an air-bone gap of at least 30 dB and more probably 40 dB, is present.***

An alternative and more encouraging way to look at the data is that ***if bone conduction is louder than air conduction then there is likely to be an air-bone gap of 10 dB or more***. This is different from saying that the Rinne test will detect a conductive defect, as it is only when the air-bone gap is greater than 40 dB that it will be detected on 90% of occasions. The reason why practising otologists have come to believe that the Rinne test is more reliable than this is that when the bone conduction is louder than the air conduction (Rinne negative) there is usually an air-bone gap. ***But what otologists tend to forget is the considerable number of occasions when there is an air-bone gap and a Rinne negative is not obtained.***

Clinical value of Rinne test

The Rinne test does not help to determine the magnitude of an air-bone gap; it is only an aid to determining whether there is a conduction defect. What the otologist needs to know in a patient with hearing impairment is whether there is a conductive component and, if this is the case, what its magnitude is. The magnitude of the air-bone gap can only be determined by using pure tone audiometry with masking.

The Rinne test has no value in patients with otoscopic evidence of middle ear pathology such as chronic otitis media, as by definition a conduction defect must be present.

However, when the ***tympanic membrane is normal*** and the bone conduction is louder than the air conduction (Rinne negative) there is most likely a conduction defect; in adults this would suggest otosclerosis. If the air conduction is louder than bone conduction (Rinne positive) in these circumstances there could still be a conductive defect due to otosclerosis of a magnitude that could benefit from surgery.

The Weber test

Why this test is so popular is unclear as it can only really be interpreted when there is a unilateral hearing impairment. One of the main problems with this test is that the ***response is not reproducible***, as can be verified by retesting a patient. ***Different results are frequently obtained depending on where the base of the fork is positioned*** *e.g.* on the nasion or on the upper lip rather than on the vertex. Most publications would agree that the results of the Weber test are ***difficult to interpret when there is a bilateral hearing impairment***.

So, assuming that it is known that a patient has a unilateral hearing impairment, ***how accurate is the Weber test*** in deciding whether it is a sensorineural or a conductive impairment? In 30% of cases the test will be referred to the midline so the result cannot be interpreted as being correct or incorrect. Of the 70% who do refer the test to one ear, about 25% refer to the incorrect ear *(Stankiewicz and Mowry, 1979)*.

It can be concluded that the Weber test is likely to add little to the assessment in the majority of patients.

Other tuning fork tests

Many other tests have been described but are infrequently used mainly because they were developed before audiometric testing was possible. They are now of historical interest as accurate audiometry is almost universally available. The Weber test in the author's opinion currently belongs to the same historical category.

Conclusions

- Clinical assessment of a patient's hearing by free-field speech can be helpful in many ways
- It is wise to have the severity of an impairment clinically assessed as audiometry can on occasions be inaccurate or not available
- In many instances the degree of accuracy that audiometry provides may be unnecessary, for example, in screening the elderly for hearing aid provision
- Exaggerated thresholds may be missed if suspicion is not aroused by clinical testing. In addition, it considerably aids the interpretation of tuning fork tests if these are carried out
- Masking is as important in clinical testing as it is in audiometric testing
- Tragal rubbing is the easiest and most appropriate method of masking to use routinely as it requires no instruments and there is no risk of overmasking
- A Barany box can potentially overmask the test ear. In free-field voice testing it should only be used when there is a unilateral profound hearing loss and in tuning fork testing when bilateral conductive impairment is likely
- If a patient can hear a whispered voice at a distance of 2 feet, his pure tone average (PTA) threshold is likely to be better than 30 dB HL
- Free-field speech testing can divide the severity of a hearing impairment into three bands *i.e.* normal, mild/moderate and severe/profound; this is sufficiently accurate for many purposes
- The Rinne test is less reliable for detecting a conductive defect than we would like to believe. Though the cross-over point from Rinne positive to

negative is an air-bone gap of ~20 dB, this means that 50% of individuals with a gap of this size will be Rinne positive (air conduction louder than bone con-duction)

- The Rinne test will not reliably detect (90% confidence) an air-bone gap until it is 40 dB or greater
- On the other hand, if bone conduction is louder than air conduction (Rinne negative) there will be an air-bone gap of 10 dB or greater. However, a con-siderable proportion of ears with clini-cally important air-bone gaps will not give this result
- The Weber test can only be interpreted when there is unilateral hearing impairment and, because of its error rate of 25% when it is referred to one ear, it is considered to add little to the clinical assessment
- For detection and quantification of a conductive defect reliance has to be placed primarily on pure tone audio-metry rather than on tuning fork tests

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Literature Search

A literature search carried out for Chapter 235 in Scott-Brown's Otolaryngology 7th Edition Hodder 2008 was updated in Nov 2012

Further reading

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