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Introduction to Reflexometry

This is a quick guide to performing and understanding reflexometry measurements. This guide should be used in conjunction with your own clinic's protocols and current research in the area of acoustic immittance testing.

What is an acoustic reflex?

The acoustic reflex is the contraction of the stapedius muscle elicited by the presentation of an acoustically loud sound.

- When either ear is presented with a loud sound, the stapedius muscles on both sides contract.
- Contraction of the stapedius muscle tilts the anterior stapes away from the oval window and stiffens the ossicular chain. This results in increased impedance which is measured as a small decrease in compliance by an ear canal probe.
- The stapedius muscle is innervated by the seventh cranial (facial) nerve (CNVII), therefore in the presence of CNVII paralysis, the stapedius muscle is likely to be affected.

Why perform reflexometry?

Acoustic reflex results make a major contribution to differential diagnosis and should be part of every basic audiological evaluation. They can provide/confirm information about the type (conductive, sensory, neural) and degree of hearing loss.

Which probe tone should I use?

Generally a 226Hz probe tone is used unless neonates are being tested. In this case a high frequency probe tone is used (1000Hz).

Definition of the Acoustic Reflex Threshold (ART)

The ART is the lowest intensity of an acoustic stimulus that elicits an acoustic reflex result (a measureable change in acoustic immittance). A change or deflection criteria of 0.03 is usually taken as the minimum change required to confirm the presence of a reflex.

Under what conditions will you measure an acoustic reflex?

An acoustic reflex will most likely be elicited if all of the following conditions are met:

1. Normal middle ear function
2. Loud enough stimulus to elicit the response
3. No abnormal adaptation to stimulus

However, about 5% of the adult population have absent acoustic reflexes.

- The pure tone intensity range to elicit an acoustic reflex is 70 to 100 dBHL , median = 85 dBHL.

- Ipsilateral ARTs in patients with normal hearing are usually 70-80dB above their pure tone thresholds, and about 5dB greater for their contralateral threshold (i.e., if pure tone thresholds were at 10dBHL, you would expect ipsilateral ARTs between 80 – 90dBHL and contralateral ARTs between 85-95dBHL as an approximation).

- ART measurements are usually conducted at 500, 1000, 2000, 4000Hz. Results are variable at 4000Hz and many normal hearing young adults have elevated ARTs at this frequency. Therefore results should be viewed with caution. Some clinicians prefer to use a Broadband Noise (BBN) as an alternate stimulus to 4000Hz. Generally, noise stimuli elicit reflexes at lower levels than pure tones do; approximately 20dB lower.

Acoustic Reflex Measurement

Acoustic reflex measurements involve presenting a loud tonal and/or noise stimuli to elicit a reflex response from the stapedius muscle. As acoustic stimulation to one ear, causes reflex contractions in both ears, and therefore we measure both the ipsilateral and contralateral reflex pathways. This is done using both an immittance probe (the same one used for tympanometry) and earphone/insert phone.
The ear with the immittance probe in it is called the *probe ear*, while the ear receiving the stimulus is called the *stimulus ear*.

For ipsilateral testing, the probe ear and the stimulus ear are one in the same (stimulus and measurement occur in the same ear). For contralateral testing, the probe ear and the stimulus ear are different (stimulus presented to one ear, while measurement occurs in the opposite ear).

If ipsilateral testing is used alone, retrocochlear disorders (e.g., intra-axial brainstem lesions) could be missed.

The correct way to refer to the measurement is based on which ear is stimulated by the loud sound. If the left ear is stimulated by the loud sound and measurement also occurs in this ear it would be a left ipsilateral acoustic reflex measurement/threshold. If the stimulus was presented to the left ear, but the reflex was recorded in the right, it would be called a left contralateral reflex measurement/threshold. Not everyone adheres to this method of reporting and therefore you should be careful when reviewing other clinician's results.

A few contra-indicators to reflex testing

- Tinnitus
- Outer ear infection
- Severe recruitment
- Hyperacusis

Reasons for repeating reflexometry

If any of the following occur during testing, it is wise to retest to confirm your results are true:

- Client swallows, talks, laughs, coughs etc during the test.
- You get an odd result that doesn't look correct or doesn't match audiogram findings. When in doubt, repeat the test to check your results are repeatable.
- Collapsed canals can lead to false results, particularly if a headphone is used on the contralateral ear. Recheck results if they look suspicious/don't fit with the other test battery of results.

Ipsilateral Pathway

The ipsilateral pathway can best be explained as follows. The loud sound travels through the outer, middle and inner (cochlea) ear, then along the vestibulocochlear nerve (CNVIII) to the brainstem arriving at the cochlear nucleus. From here the signal travels to the superior olivary complex and to the CNVII nuclei. The signal is then sent down the CNVII causing contraction of the stapedius muscle.

Below is a simplified diagram to understand the pathway.

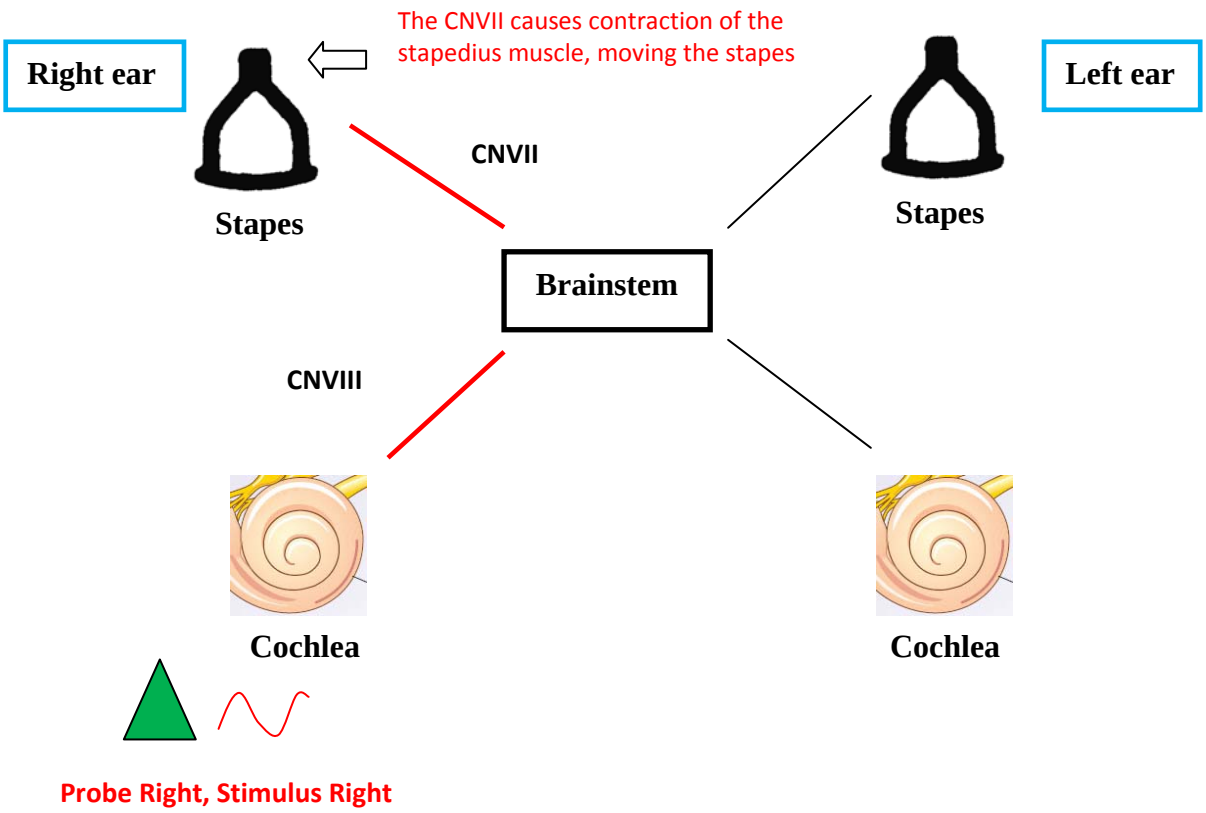

Diagram 1. *Ipsilateral reflex pathway. In this example the tone is elicited in the right ear and the response is recorded in the same ear. The stimulus travels up the CNVIII to the brainstem, which causes the CNVII to contract the stapedius muscle. If either nerve has a lesion or the sound is not loud enough when it reaches the cochlea (e.g. conductive loss) an acoustic reflex would not be present for the right ear.* (Images from www.emeraldinsight.com & www.openlearn.open.ac.uk).

Contralateral Pathway

In the contralateral reflex pathway, the loud sound travels through the outer, middle and inner (cochlea) ear, then along the CNVIII to the brainstem arriving at the cochlear nucleus. From here the signal travels to the other superior olivary complex and the other CNVII nuclei. The signal is then sent down the CNVII causing contraction of the stapedius muscle.
Below is a simplified diagram to understand the pathway.

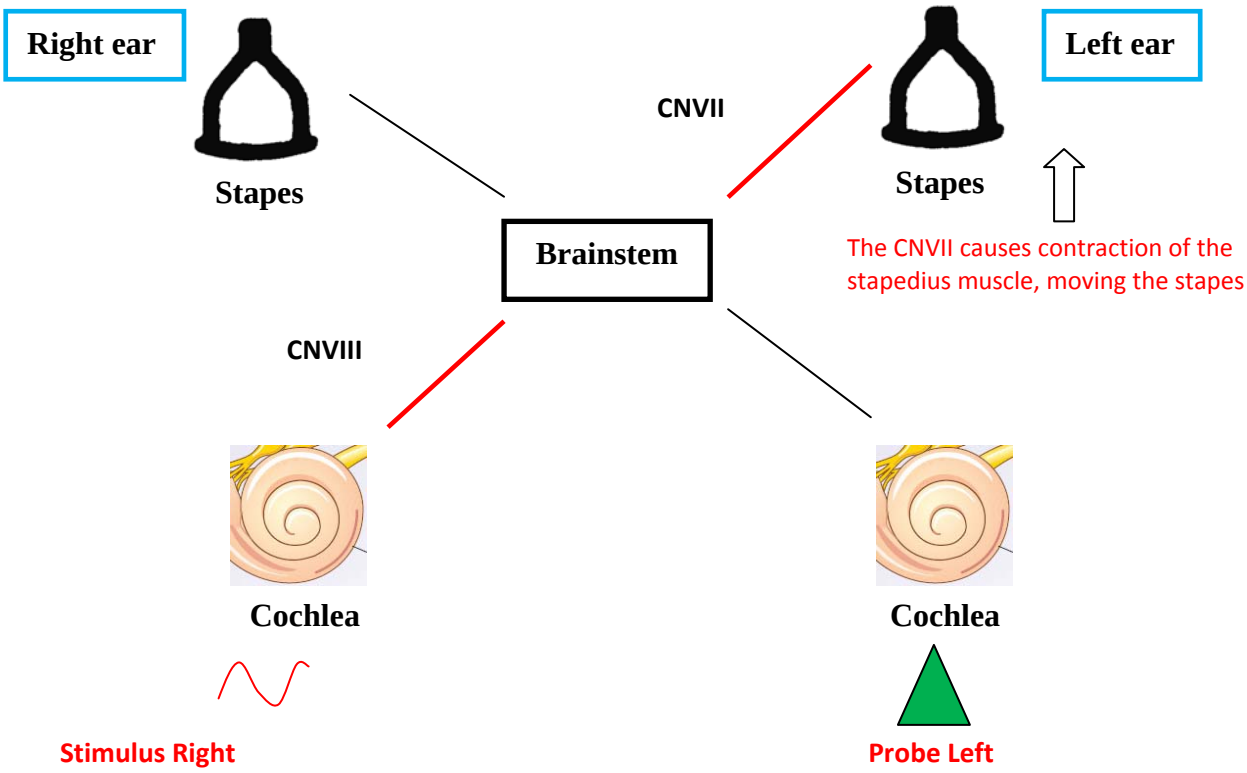

Diagram 2. *Contralateral reflex pathway. In this example the tone is presented to the right ear, but recorded by the probe in the left ear. Even though the stimulus is presented to the right ear, the stapedius muscle contracts on both sides and an acoustic reflex should be present in the left ear assuming all is normal. If either CNVIII in the right ear or the CNVII in the left ear has a lesion or the sound is not loud enough when it reaches the cochlea (e.g. conductive loss) an acoustic reflex would not be recorded in left ear.* (Images from www.emeraldinsight.com & www.openlearn.open.ac.uk).

A more detailed description of the pathways can be found in the references at the end of this document. In particular, see (Emanuel, 2009).

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Procedure for obtaining acoustic reflex thresholds

1. Alert the client that they will hear some loud sounds in either ear. Ask them to sit still and quiet.
2. Place the immittance probe (probe used for tympanometry) into the ear you want to test. Place the contralateral probe into the other ear.
3. Perform tympanometry first. Acoustic reflexes should be measured with the ear canal pressure set to obtain maximum compliance in the presence of the 226Hz probe tone (i.e., after tympanometry).
4. Depending on the required outcome of testing (screening vs clinical) it is not recommended to go above 105dBHL unless you suspect a conductive loss.
5. Present tones at @ 0.5, 1, 2, 4 kHz &/or BBN starting from 70-80dBHL up to 105dBHL in 5dB steps until an acoustic reflex threshold is obtained. Tones should be presented for 1-2 seconds in duration.
6. If the tone is loud enough and a contraction of the stapedius muscle occurs, the immittance probe will record that an acoustic reflex is present.
7. The presence of a reflex should be confirmed to rule out artefacts. Confirmation of a reflex can be done by repeating presentation at the same intensity level or testing for a reflex 5dB above the ART obtained.
8. Record the results. For no response enter "X", "NR" or "↓ 105" indicating no response up to and including 105dBHL. This indicates to the reader what intensities you have included in your testing.

Note: Acoustic reflex testing can cause permanent hearing damage and tinnitus and while there are no standards for safe presentation levels, most of the literature recommends testing no higher than 105-110dBHL.

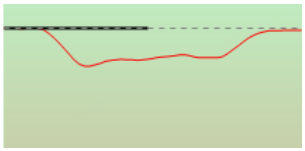
What characteristics am I looking for in my results?

- the presence or absence of the stapedial reflex
- an acoustic reflex threshold
- acoustic reflex decay or adaptation (if tested)

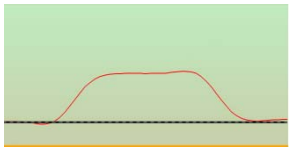
What is and isn't a reflex?

The following are some examples of what a reflex should look like. With some equipment, such as the Interacoustics Titan, the software will alert you when a reflex is present. However, detection is based on the measurement matching an algorithm. It is therefore important for the clinician to look at the morphology of the reflex in conjunction with your testing situation (client talking, swallowing) and decide if the reflex is in fact a "true" reflex and not an artefact.

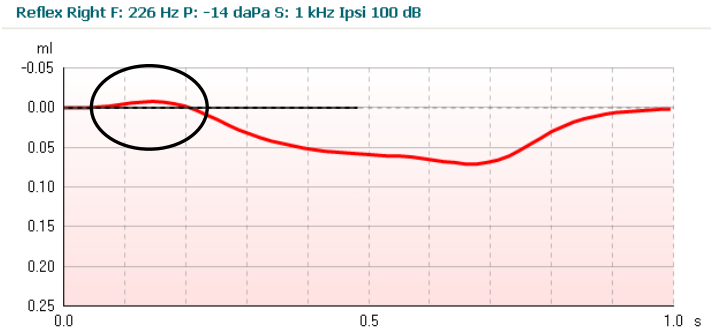
Reflexes will either be displayed positively and negatively, depending on your equipment. Typically, in Australia they are displayed negatively.



A negatively displayed reflex



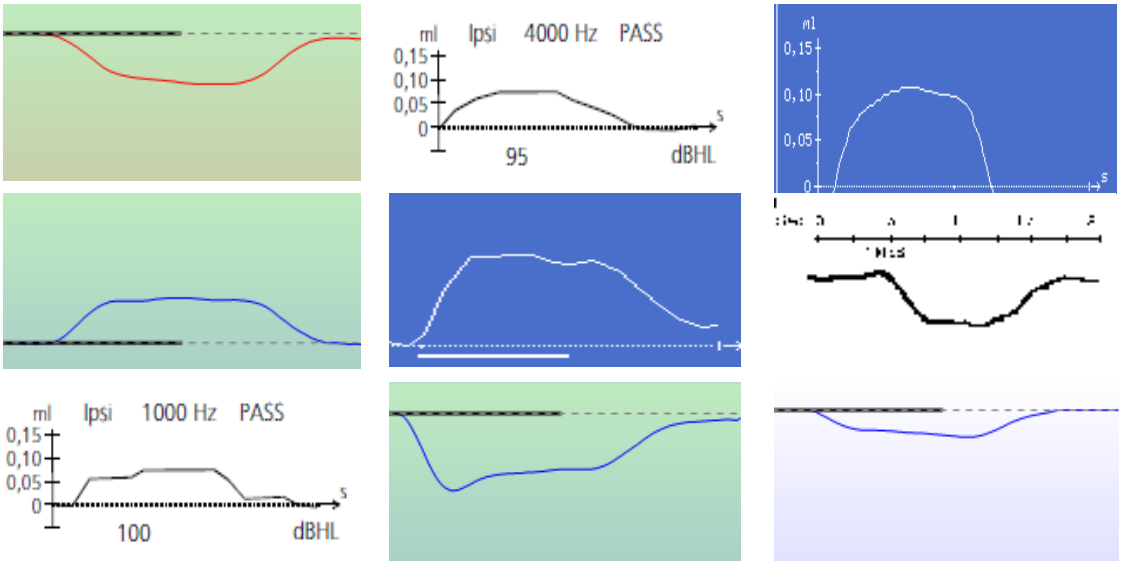
A positively displayed reflex



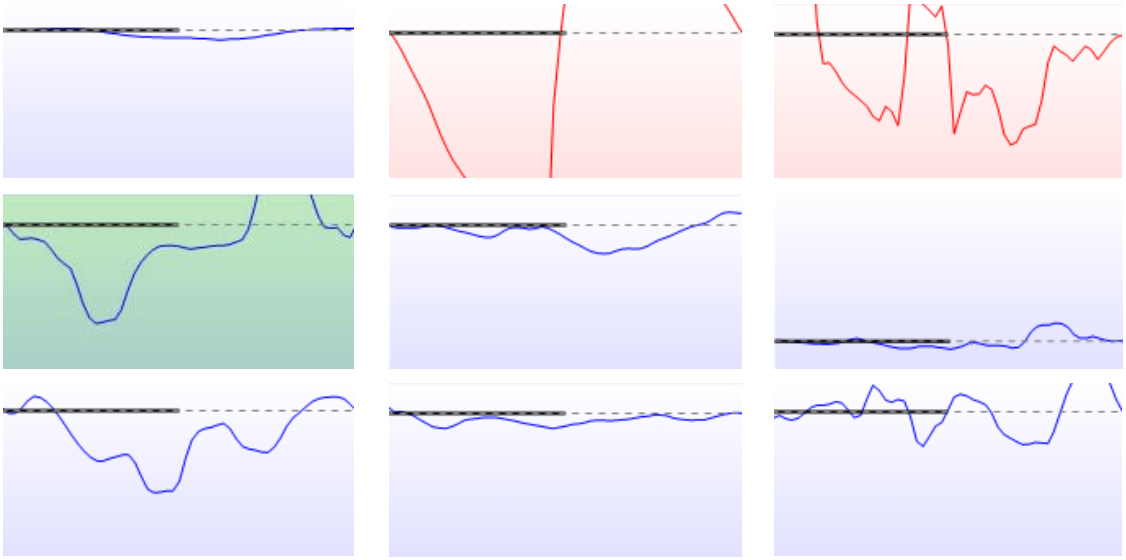
A reflex should show a downward deflection from 0.00ml which is time-locked to the stimulus presentation. It will then hold the change in compliance before offsetting back to 0.00ml.

You will note in the above example that the reflex goes into the negative part of the graph (see inside black circle) before moving to the positive deflection point of 0.05ml. This type of response is called biphasic and can occur at the onset or both onset and offset of the reflex. The abnormal pattern of a biphasic response at both onset and offset is associated with otosclerosis, particularly in its early stages.

<u>These are reflexes:</u>



<u>These aren't:</u>



Why aren't these images reflexes? In all but one example (highlighted green), the system has detected that these are not reflexes. In most of these examples, the client has either moved, swallowed or spoken during the test which has created an artefact.
In the first example, while it may appear to be a reflex, it has not been accepted as one because it has not met the deflection criteria as set by the instrument.
In the fourth (green highlighted) example, the system has detected this as a reflex, but in fact it's an artefact. You tell by looking at the shape that it does not match the pattern of a reflex. In this instance, you should repeat the test at that frequency to confirm the true ART.

Acoustic Reflex Patterns

Below are nine examples of reflex patterns you may come across during testing. However, you should be aware that these are not the results/patterns that you will see every time you test and real life clinical interpretations are much more complex. Different authors publish patterns/record results in different ways and therefore these tables below are a guide only.

Note that reflexes at 4000Hz may or may not be present due to variability at this frequency (discussed earlier). You may wish to use a BBN as an alternative to testing at 4000Hz.

Normal hearing and middle ear function

Generally for clients with normal hearing and normal middle ear function, both ipsilateral and contralateral reflexes will be present at all frequencies.

Example 1: Normal hearing/middle ear function

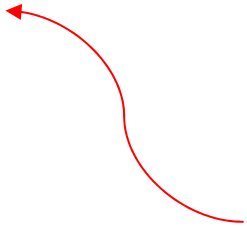
	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	85	85	85	85
	Stim L (contra)	90	90	90	90
Probe L	**Stim L (ispi)**	80	80	80	80
	Stim R (contra)	85	85	85	85

Conductive Hearing Loss

Acoustic reflexes will be absent when a probe is placed in an ear with a middle ear disorder. This is due to the fact that middle ear disorders typically prevent the probe from measuring a change in compliance when the stapedius muscle contracts. Reflexes will therefore be absent even in the case of a mild conductive hearing loss. In the presence of a Type C tympanogram, depending on the degree of negative pressure in the middle ear, reflexes can be either present or absent.
If acoustic reflexes are present in the probe ear, it is unlikely that a conductive hearing loss exists, except in the rare case of Superior Semicircular Canal Dehiscence (SSCD).

Example 2: Normal hearing in the right ear & a mild conductive loss in the left ear

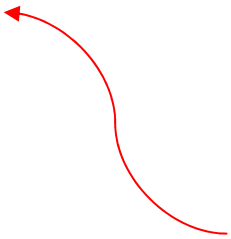
	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	85	85	85	85
	Stim L (contra)	100	100	100	105
Probe L	**Stim L (ispi)**	X	X	X	X
	Stim R (contra)	X	X	X	X



In this example, the raised left contralateral reflex thresholds (probe right, stimulus left) are due to the additional SPL needed to overcome the mild loss in the L ear. The mild middle ear pathology may affect signals travelling through the left ear or being measured in the left ear. They will either be absent or raised.

Example 3: Normal hearing in the right ear & a moderate conductive loss in the left ear

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	85	85	85	85
	Stim L (contra)	X	X	X	X
Probe L	**Stim L (ispi)**	X	X	X	X
	Stim R (contra)	X	X	X	X



In this example, because of the moderate loss in the left ear, the stimulus (even at max levels) was not loud enough to elicit the stapedius reflex in the left contralateral recording (probe right, stimulus left).

Cochlear Hearing Loss

In ears with a cochlear hearing loss, it is possible for the acoustic reflex to be elicited at sensation levels (SL) of less than 60dB. The SL is the difference between the ART and the hearing threshold. For example, if the hearing threshold at 1kHz is 50dBHL and the ART is 90dBHL, the sensation level is 40dBSL.
When the SL is less than 60dB, a positive Metz test is indicated. This indicates a cochlear site of lesion (sensorineural loss) due to the loudness recruitment phenomenon.

Example 4: A mild to moderate cochlear loss in both left & right ears

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	85	80	80	100
	Stim L (contra)	85	90	90	X
Probe L	**Stim L (ispi)**	85	90	85	100
	Stim R (contra)	90	80	85	X

In this example, note that the ARTs occur at about normal levels. This is because the acoustic reflex threshold in an ear with a cochlear loss may resemble the results of a normal ear when the air conduction thresholds are below about 50dBHL. As the hearing threshold increases above this level, the chance of recording a raised or absent acoustic reflex increases.

Example 5: Severe to profound cochlear loss in left ear, normal hearing in the right ear

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	85	85	85	95
	Stim L (contra)	X	X	X	X
Probe L	**Stim L (ispi)**	X	X	X	X
	Stim R (contra)	90	90	90	95

In this example, the stimulus (even at max levels) was not loud enough to elicit a stapedius reflex due to the severe/profound loss in the left ear. Therefore whenever a stimulus is presented to the affected ear, reflexes will be absent/raised in both ipsilateral and contralateral recordings as shown above.

Retrocochlear Hearing loss

ARTs in ears with retrocochlear (CNVII) pathology are usually elevated above what they would have been for normal hearing or a cochlear hearing loss. Often they are absent at maximum stimulus levels. Keep in mind that ART results should be analysed in combination with the patient case history, audiogram, speech and tympanometry findings for differential diagnosis.

Some things to note:

- Ears with retrocochlear pathology and normal hearing do not have reflexes 30% of the time
- With a mild 30dB hearing loss, the likelihood of absent reflexes increases.
- The absence of reflexes at 0.5, 1 & 2kHz in the presence of normal/near normal hearing must be considered suspicious unless proven otherwise.
- The affected ear will show absent acoustic reflexes when a stimulus is presented to it in the case of CNVIII lesions.

Example 6: Retrocochlear lesion in the left ear; normal hearing in both ears

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	80	80	80	90
	Stim L (contra)	105	110	X	X
Probe L	**Stim L (ispi)**	110	X	X	X
	Stim R (contra)	85	80	85	95

In this example, note the raised/absent acoustic reflexes with presentation to the left ear.

Example 7: Retrocochlear/CNVIII lesion in the left ear; a mild hearing loss in the left ear & normal hearing in the right ear

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	80	80	85	85
	Stim L (contra)	X	X	X	X
Probe L	**Stim L (ispi)**	X	X	X	X
	Stim R (contra)	85	85	90	90

In this example, note the absent acoustic reflexes when sound is presented to the left ear.

Facial nerve/CNVII involvement

Acoustic reflexes are absent when measured on the affected side in the case of a facial nerve disorder (e.g., probe in the affected ear). This is because the stapedius muscle is innervated by the CNVII.
Often, CNVII disorders are easily recognizable (e.g., facial paralysis in the case of Bell's Palsy) and measurement of the acoustic reflex is used as a tool to monitor the recovery process in such patients.

Example 8: Facial nerve/CNVII lesion in the left ear due to Bell's Palsy; normal hearing in both ears

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	80	80	85	85
	Stim L (contra)	85	85	85	90
Probe L	**Stim L (ispi)**	X	X	X	X
	Stim R (contra)	X	X	X	X

In this example, note that the acoustic reflexes are absent when the probe is coupled to the affected (left) ear. Also, you will recognise this is a similar pattern of results for an CNVIII lesion.

Intra-axial brainstem lesion

- Very rare. About 1 in 10 million.
- Acoustic reflexes are normal ipsilaterally and absent contralaterally. The left and right pathways are disrupted by a lesion involving the auditory fibres.

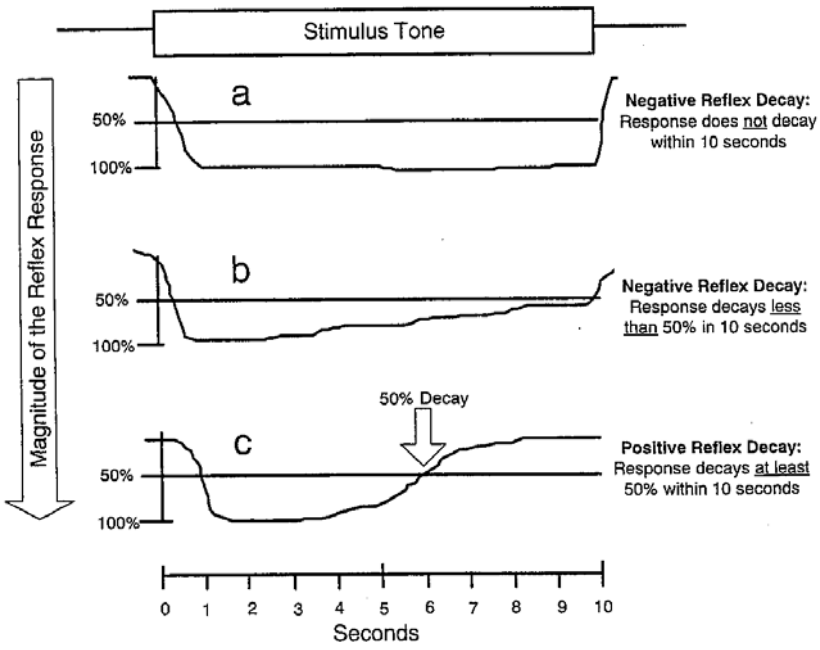
Example 9: Intra-axial brainstem lesion; normal hearing in both ears

	Freq	.5kHz	1kHz	2kHz	4kHz
Probe R	**Stim R (ispi)**	80	80	85	85
	Stim L (contra)	X	X	X	X
Probe L	**Stim L (ispi)**	85	80	80	85
	Stim R (contra)	X	X	X	X

Reflex Decay Testing

Reflex decay testing can be useful in detecting/confirming retrocochlear pathology in patients. Generally patients will present with typical retrocochlear indicators (unilateral tinnitus, asymmetrical hearing loss, dizziness/vertigo) and you will have enough information to warrant a referral to an ENT specialist without needing to do this test. This test may be useful though when the audiogram and case history are normal, but reflex results show a retrocochlear pattern.

An acoustic reflex decay test measures whether a reflex contraction is maintained or weakens during continuous stimulation (usually 10 seconds). Testing is usually conducted at 500Hz and 1000Hz, but not above these frequencies as even normal ears can show decay at higher frequencies.
The test is performed by presenting a continuous stimulus 10dB above the ART for that frequency for a period of 10 seconds. Either the magnitude of the reflex response will stay the same or decrease over the 10 second period. What you are looking for is whether or not the response decays to half its original magnitude. Therefore if the reflex response decreases to 50% of its original magnitude within the 10 seconds of testing, the test would be positive for reflex decay.



In the figure above (taken from Gefland, 2001), the acoustic reflex decay is considered negative if the reflex response does not decrease (example a) or if it decreases by less than half of its original magnitude (example b). Reflex decay is positive if the magnitude falls by 50% or more (as in example c).

How to perform a reflex decay test

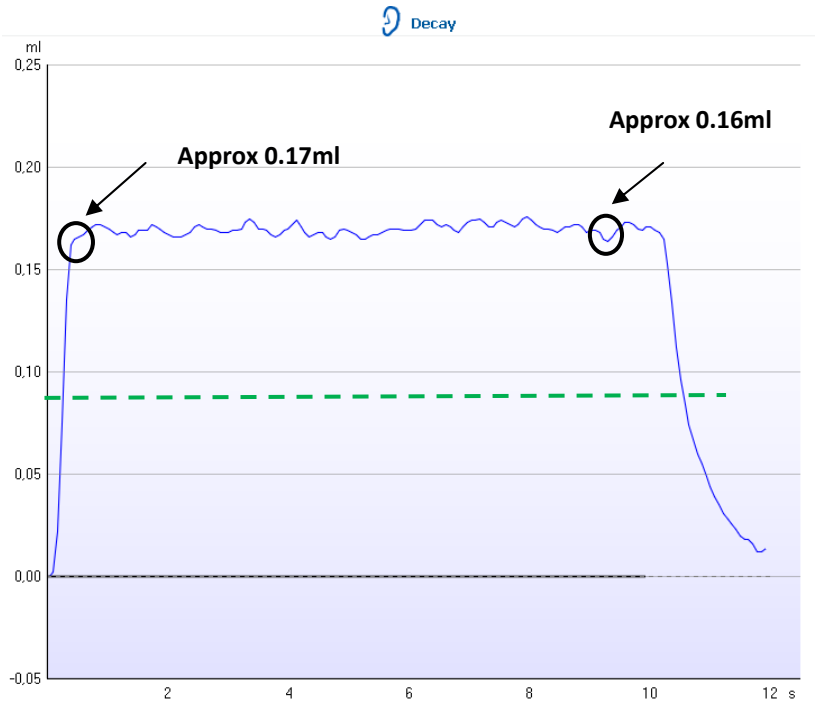
(Many tympanometers will include an in-built reflex decay test option)

1. Perform tympanometry and reflexometry first.
2. Take the acoustic reflex threshold at 500Hz or 1000Hz in the ear you want to test and add 10dB. This is the stimulus level you will use for testing (e.g., if the reflex threshold was 80dB at 1000Hz, you would test at 90dB at 1000Hz).
3. Go to the reflex decay test option.
4. Make sure you have a good seal between the probe and the ear and then press start to run the test.

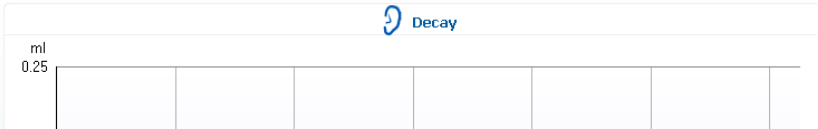
Note: If the reflex decay test is positive, you should check that it was not due to an improper seal, which might produce an artefact similar to a decaying curve.

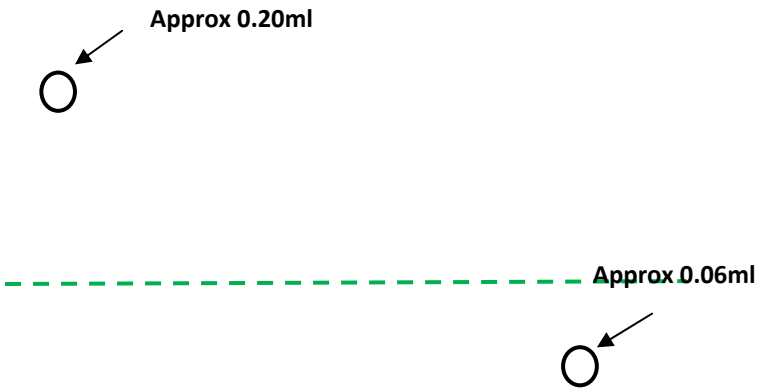
Analysing the results

Look at the recorded measurement. Typically you will see a result similar to the example below.
The decay value is the percentage difference of the two reflex deflection values taken half a second after the stimulus started and half a second before the stimulus stopped.



Example 1. In this example, the reflex decay test is negative as the response did not decay by more than 50% (drop below green dotted line), during the 10 second test interval. The blue reflex line would have had to have dropped below the green dotted line for positive reflex decay to be measured.





Example 2. This example shows a positive reflex decay measurement. The reflex has decayed by more than 50% (indicated by the green dotted line) during the 10 second test interval.

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