The detection of dead cochlear regions: TEN test

PRODUCT INSIGHTS

author:
Elisa Veronese, Ph.D.

The TEN test is used as a practical investigation tool for the detection of dead cochlear regions. It is based on the use of a background noise from which it takes its name, the Threshold-Equalizing Noise (TEN), in the presence of which the patient's auditory threshold is measured. It was developed and validated by the research group of professor Brian C.J. Moore of the University of Cambridge [1] and nowadays it is considered one of the most reliable and easy-to-perform test in daily clinical practice for the search for cochlear disorders.

The diagnosis of dead cochlear regions is particularly useful if a clinician is considering the possibility of prescribing a hearing aid to a patient: at the frequencies associated with dead regions, in fact, the device may not guarantee the patient the expected amplification. The outcome of the TEN test represents in these cases a valid diagnostic support and counseling tool, useful for deciding with the patient if the reachable amplification can satisfy his\her needs. Alternatively, the TEN test is a valid tool for deciding whether the patient is a good candidate for a cochlear implant.

TEN TEST

In a normal hearing ear, the vibrations of the basilar membrane are influenced by the activity of outer hair cells (OHC), which control what is called the "active mechanism" in the cochlea [2], increasing the amplitude of the vibration, thus improving the response to weak sounds and refining the tuning on the basilar membrane. The amplified vibrations are then detected by internal hair cells (IHC), which release neurotransmitters activating a response in the auditory nerve.

While a cochlear hearing loss up to about 55 dB HL may be due to damage of the OHC alone, a hearing loss above 55 dB HL almost always involves a joint impairment of OHC and IHC [3]. The simple registration of an audiogram does not allow to determine what proportion of the hearing loss is due to the damage of the OHC, and what to the damage of the IHC.

Cochlear regions in which either IHCs are completely non-functioning or the neurons that innervate a basilar membrane area do not transmit any stimulus are referred to as dead regions.

In a dead region, vibrations of the basilar membrane are never detected: if, for example, the IHC at the basal end of the cochlea (associated with high frequencies) do not work, the neurons connected to this zone will never be stimulated. However, a high frequency pure tone can be detected if it produces a vibration on the basilar membrane sufficient to involve a region adjacent to the basal extremity, associated with lower frequencies: the high frequency sound can be detected by neurons on adjacent frequencies (off-frequency listening). In this case the audiogram is misleading, since the actual hearing loss at a given frequency may be more severe than that suggested by the audiometric threshold at that frequency. Furthermore, the off-frequency listening makes it difficult to identify dead cochlear regions using pure simple tones as stimuli.

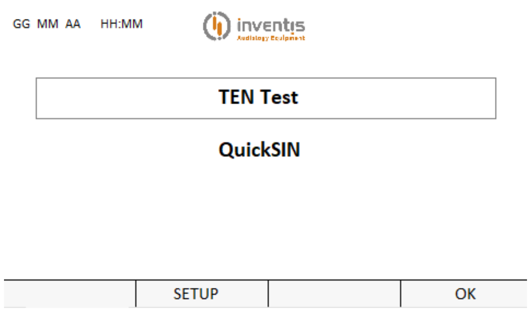
The TEN test includes the measurement of the threshold for the detection of a pure tone sent in the presence of a background Threshold-Equalizing Noise (TEN).

When the pure tone frequency corresponds to the frequency associated with a dead region, the stimulus will be perceived only if it generates a vibration of the basilar membrane even in an adjacent healthy region. The amount of vibrations produced by the tone in the healthy region will be lower than in the dead region and will therefore be easily masked by the noise: consequently, the threshold of the masked stimulus will be significantly higher than the unmasked threshold. The practical rule proposed by Moore suggests that a dead region at a particular frequency is detected when

1. the masked threshold exceeds the unmasked threshold by at least 10 dB
2. the masked threshold exceeds at least 10 dB the nominal level of the noise in dB HL.

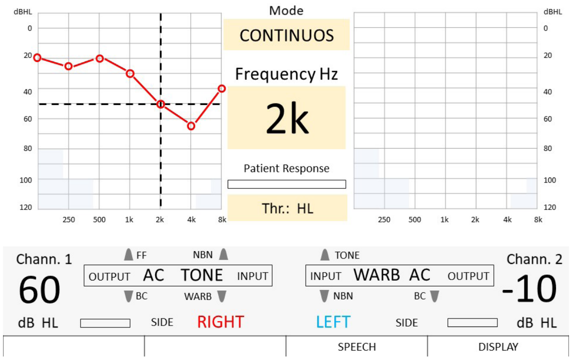
HOW TO PERFORM THE TEST WITH INVENTIS DEVICES

The TEN test can be performed with different Inventis devices, i.e. Harp Plus (optional, available under license), Piano Basic, and Piano Plus. Sounds are presented either with supraural headphones or with insert earphones. Test material is recorded on two channels: channel one



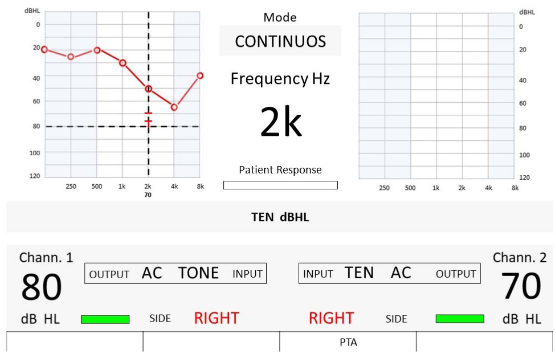
is for stimulus, channel two is for noise.

To perform the test, it is mandatory to have previously assessed the patient's pure-tone threshold levels



between 500 and 4000 Hz.

Afterwards, the user can access the TEN test screen from the main menu and see the pure tone audiogram displayed on the background of the graph. During the execution of the exam, the noise must be added to each frequency of the pure tone signal with a level at least 10 dB above the threshold. Tone and noise are presented ipsilaterally. As stated by Moore [1], if the masked threshold is 10 dB or more above that of both the



threshold and the TEN noise, the cochlea is considered "dead" at that frequency.

On Harp and Piano, the TEN test has its dedicated screen accessible from the main menu. Here, the user can set the side to be stimulated and the intensities relative to the stimuli and noise. During the TEN test it is possible to choose between a continuous or a pulsed stimulus. It is also possible to enable the tracking or lock options.

Stored masked thresholds are displayed on the audiogram using "T" symbol. The corresponding masking level, in dB HL, is indicated in the lower part of the graph.

Moore suggests some rules to set the intensity of the noise [4], in particular:

- for frequencies where the hearing loss is less than or equal to 60 dB HL, set the TEN level to 70 dB HL. This is not unpleasantly loud for most people, and it leads to a definitive result;
- for frequencies where the hearing loss is 70 dB HL or more, set the TEN level 10 dB above the audiometric threshold at that frequency;
- if the TEN is judged unpleasantly loud, or if the maximum TEN level of 90 dB HL is reached, then the TEN level can be set equal to the audiometric threshold. This should still give a definitive result.

It may be difficult or impossible to apply the TEN test when the hearing loss at the test frequency is 90 dB HL or more, although it is quite likely that a dead region would be present with such a severe hearing loss.

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INVENTIS S.r.l.
CORSO STATI UNITI, 1/3
35127 PADOVA – ITALIA
TEL: +39.049.8962 844
FAX: +39.049.8966 343
info@inventis.it
www.inventis.it