Detecting Cochlear Dead Regions in the Audiology Clinic

What are cochlear dead regions?
In a recent interview for this magazine, Prof Brian Moore recalled how he introduced the term ‘dead regions’ to describe areas of the cochlea with few or no functioning inner hair cells.2 Using the actual words ‘dead regions’ can be somewhat emotive (and best avoided in the clinic) but nevertheless, the term has been widely adopted in audiology.

Since the cochlea is tonotopic – each place along its length responds optimally to a different frequency – a dead region can be characterised by the range of frequencies where the inner hair cell function is lost. An adjacent area of the cochlea with residual inner hair cell function may detect these frequencies, but a high signal level may be needed to achieve this. The detection of a signal via the ‘wrong’ place in the cochlea is known as ‘off-frequency listening’.

The gold standard test for detecting off-frequency listening is to measure psychophysical tuning curves (PTCs), but this is too time consuming for routine clinical use, even using a ‘fast PTC’ method.3 The TEN(HL) test developed by Prof Moore and colleagues offers a faster method of testing at audio-metric frequencies between 0.5 and 4kHz and makes use of equipment already in the clinic.

When to test for dead regions
With considerable time pressures in a busy hearing aid clinic, rather than using the TEN(HL) test with everyone, our approach is to use the test where its outcome may affect clinical management. This might be in:

- counselling expectations
- adjusting hearing aid gain
- selecting a hearing aid
- choosing which ear to aid
- supporting the referral for a cochlear implant assessment.

We routinely test people seen in a clinic for severe to profound hearing losses where the aim is to optimise their hearing aid provision and consider referral to a cochlear implant centre. In other clinics, the decision to use the TEN(HL) test is often triggered by:

- complaints of distorted sound
- difficulty in distinguishing musical pitches
- poorer speech recognition than might be expected from the audiogram
- a steep slope in the audiogram

Table 1. TEN test results for the right ear (levels and thresholds are in dB read from the audiometer dial. NR indicates no response).

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Tone threshold from CD</th>
<th>TEN level</th>
<th>Tone threshold with TEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>84</td>
<td>94</td>
<td>104 NR</td>
</tr>
<tr>
<td>750</td>
<td>not tested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>76</td>
<td>86</td>
<td>104 NR</td>
</tr>
<tr>
<td>1,500</td>
<td>70</td>
<td>80</td>
<td>92</td>
</tr>
<tr>
<td>2,000</td>
<td>80</td>
<td>90</td>
<td>104 NR</td>
</tr>
<tr>
<td>3,000</td>
<td>62</td>
<td>76</td>
<td>86</td>
</tr>
<tr>
<td>4,000</td>
<td>58</td>
<td>70</td>
<td>78</td>
</tr>
</tbody>
</table>
Setting up the audiometer
Testing simply requires:
- a two-channel audiometer with TDH 39, 49 or 50 headphones
- a TEN(HL) CD
- a stereo CD player with suitable leads to connect to the audiometer.

The audiometer needs to be capable of accepting two external inputs (often labelled Ext A and Ext B), corresponding to the two channels of the stereo signal from the CD. The test works with both stand-alone audiometers and computer controlled audiometers. The CD player can be a stand-alone system, or a computer’s media player, providing that it uses a good quality sound card.

The TEN(HL) CD consists of eight stereo tracks – one calibration track and one for each of the test frequencies. On each of the test frequency tracks, the left channel coming out of the CD player carries the same broadband Threshold Equalising Noise (TEN), and the right channel carries a test tone at the frequency of interest.

With the equipment connected as shown in the diagram, direct Ext B to Channel 1 of the audiometer and Ext A to Channel 2. This gives a set-up familiar to audiologists where Channel 1 controls a tone and Channel 2 controls the noise. Some audiometers, for example Otometrics’ Aurical, need to be switched to the speech audiometry screen to play an external input. In this case, the controls shown on the screen relating to speech recognition scores can be ignored. The audiometer is simply used to set the levels and to present the noise and tone from the CD.

Before testing, set the step size to 2dB and direct both audiometer channels to the test ear. Play the calibration track (Track 1) from the CD and adjust the levels of the external inputs to show zero on the VU meters. (Note that when the test tracks are played, the Channel 1 VU meter will read below 0dB and the Channel 2 VU meter will read higher than 0dB.)

How to do the test
Testing all frequencies on the CD in both ears usually takes about 15 minutes, but in many cases, only a few frequencies are required. Start where off-frequency listening is not suspected – this allows the person being tested to practise the task. Next, test frequencies that might affect hearing aid settings. Lastly, test any other frequencies for counselling.

For each frequency:
1. Measure the not-masked threshold in 2dB steps using the tone from CD. It may differ slightly from the threshold measured using the audiometer-generated tone.
2. Choose the level for the TEN for this frequency – levels are as shown on the audiometer dial.
   - If the hearing loss is less than or equal to 60dB, set the TEN level to 70dB HL.
   - If the hearing loss is more than 60dB, set the TEN level 10dB above the pure tone threshold measured in Step 1.
     For example, if the audiometric threshold is 75dB HL, set the TEN level to 85dB HL.
3. Before introducing the TEN, reinstruct the person to ignore the noise, warn them that it may be loud and ask them to indicate if it is uncomfortable. Every time the TEN is introduced, turn the level up gradually and watch for loudness discomfort.
   - If the TEN is unpleasantly loud, or if the maximum TEN level of about 90dB HL is reached, then the TEN level can be set equal to the pure tone threshold measured in Step 1.
Since the cochlea is tonotopic a dead region can be characterised by the range of frequencies where the inner hair cell function is lost.

4. With the TEN presented continuously to the test ear, measure the masked threshold for the tone. (The initial presentation level of the tone must be higher than the TEN level.)

What do the results mean?
A positive result, indicative of off-frequency listening, is obtained when the masked threshold is 10dB or more above the level of the TEN.

As well as cochlear dead regions, positive results can be recorded in cases of:
- retrocochlear lesions
- Ménière’s disease
- auditory neuropathy
- central auditory system disorders

These pathologies are all associated with poor speech discrimination, particularly in noise. A positive test result can reinforce the need for good listening tactics or assistive listening devices.

The TEN test in practice
Table 1 shows the levels used for a TEN(HL) test on the right ear of a lady with very poor speech discrimination (9% word recognition score, bilaterally aided without lipreading). Figure 2 shows her audiogram. Her thresholds in the presence of the TEN were abnormally raised between 0.5 and 3kHz in the right ear. Similar results were obtained from the left ear.

She has subsequently received a cochlear implant with a successful outcome.

Tuning hearing aids
Studies have shown benefit in amplifying frequencies that are some way beyond the edge frequency into the range of a dead region. As a starting point, for high frequency dead regions, amplify only up to 1.7 x edge frequency; for less common low frequency dead regions, amplify down to 0.57 x edge frequency.10,11 Take as the edge frequency the first frequency where the TEN test gives a positive result.

A reduction in high frequency gain allows more open coupling to the ear and may result in a smaller, lower power aid being prescribed. However, be flexible based on the wearer’s subjective preferences. The hearing aid user with the audiogram shown in Figure 3 has bilateral high frequency dead regions with edge frequencies at 2kHz. Reducing his hearing aid gain at 4kHz and above has lessened problems with feedback and allowed him to wear more comfortable earmoulds.

Frequency lowering hearing aids are now available commercially, using either frequency compression or transposition. They can improve audibility of sounds falling within a high frequency dead region, but as yet there are no guidelines on the optimum settings for ears with dead regions. Not surprisingly, this is an area of active research.

Conclusion
Testing for cochlear dead regions can inform decisions on amplification. In this context, the TEN(HL) test is a useful clinical tool.

References