Minutes of the Sixth Ordinary Meeting

Held on Thursday 6th February 2020

Joint Meeting with the Institute of Physics

'Audiology – Breaking the Sound Barrier'

Dr Martin O'Driscoll, Consultant Clinical Scientist (Audiology), Manchester Royal Infirmary

Dr O'Driscoll was introduced by Dr Steve Ryan, President, Liverpool Medical Institution.

Dr O'Driscoll began his career in healthcare science as a medical physicist in Nuclear Medicine at the Royal Liverpool Hospital in 1985. Whilst there, he successfully completed the Leeds M.Sc. in Medical Physics. In 1991, he moved to Southampton to study for the M.Sc. in Audiology and became a Grade A Clinical Scientist (Audiology) in Reading. In 1993, he moved to the Audiology Department and Hearing Implant Centre at the Manchester Royal Infirmary where he is now Consultant Clinical Scientist (Audiology). He has completed a part-time PhD in Manchester in electrophysiology of the auditory brainstem.

Dr O'Driscoll began his talk with a question. What is audiology? His answer is that it is a combination of the Science of Hearing; Balance; Communication; Diagnostic Testing; Hearing Technology and Rehabilitation & Counselling and that it affects all ages.

By way of background, he showed the structure of the ear with the pinna, ear canal, ear drum, middle ear and the inner ear (the cochlea) followed by a description of how sound vibrations in air are transmitted via the ear canal and middle ear to the inner ear. He noted that the resonant frequency of the ear canal is approximately 2 kHz. He commented on the tonotopicity (pitch order) of the inner ear which discriminates between high and low frequencies.

Regarding hearing loss, he noted that this can be "Conductive" or "Sensorineural" or a combination of the two.

Conductive hearing loss, occurs in the outer and middle ear, it can be temporary or permanent and, as a common example in children, he cited fluid in the middle ear, namely "Glue Ear".

Sensorineural hearing loss, occurs in the inner ear and is caused by damage to the cochlear sensory hair cells. It is rarely caused by damage to the cochlear or hearing nerve. A sensorineural hearing loss is usually permanent and can arise from a range of conditions (e.g., genetic, noise exposure, infection, trauma, medication, tumours or can be age related).

To illustrate the loudness of noise that can cause hearing loss, he displayed a "thermometer" display with 0 decibels as the threshold of normal hearing, with noise levels under 75 dB causing negligible hearing damage (shown in Green on the thermometer), between 75 and 85 dB (shown in Amber) and above 85 dB shown in Red – prolonged exposure to sounds above 85 dB can cause damage to the cochlear sensory hair cells.

He then gave a description of how hearing loss is measured. There is "Air Conduction" and "Bone Conduction". The former is with the patient wearing headphones through which sound waves are transmitted down the ear canal and the latter is where a vibrating transducer is placed on the bone behind the ear and the vibrations pass through the skull directly to the inner ear (cochlea).

To quantify hearing loss, an audiogram is generated. This is a chart of loudness (in decibels, dB) increasing downwards on the vertical axis with the horizontal axis being pitch (i.e., sound frequency) in cycles per second (Hertz, Hz). The pitch usually ranges from 125 Hz to about 8 kHz and the loudness from 0 dB to about 120 dB. With normal hearing, the hearing thresholds are better than 20 dB on the audiogram.

Dr O'Driscoll showed typical audiograms of patients having increasing hearing loss (HL). These range from mild in which the hearing thresholds are up to 40dB to severe/profound where the hearing thresholds are greater than 80 dB across the frequency range

He noted that the patient's perceptual consequences of cochlear damage are poor sensitivity, reduced dynamic range, the inability to resolve between different frequencies and the inability to resolve closely spaced sounds.

He went on to discuss the impact that HL can have on a particular patient. He noted that for children, the development of spoken language and communication skills are impaired and there is reduced early reading skills (with consequent reduced academic achievement). For adults with unmanaged hearing loss there is an impact on mental health and physiological well-being, reduced employment opportunities and behavioural and emotional problems.

He quoted statistics from *The Lancet, **36** (2) 2019,* which reported a clear association between an increase in cognitive decline and dementia in patients with hearing loss.

How prevalent is HL in the UK? He quoted figures from *Action on Hearing Loss, 2016*,
Namely that there are > 10 million people in the UK (about 1 in 6) with some form of hearing loss of which 800,000 are severely or profoundly deaf. There are about 0.1% of children born in the UK with severe/profound HL each year. For adults, it takes, on average, about 10 years from the onset of hearing loss before they will seek help. Hearing loss is more prevalent with age, 42% of over 50s have HL with the figure rising to 71% in the over 70s.

Hearing aids have a definite and useful role in early management of HL. Generally, hearing aids make speech audible and modern digital devices with sound processing can reduce acoustic feedback and ensure amplification is within a comfortable range. Hearing aids amplify frequencies in the range of 250 Hz to about 6 kHz. They are programmable and can compress high frequencies into a lower frequency region. They can be small open fit devices for patients with mild/moderate HL. For patients with severe/profound HL, a tailored ear mould would be appropriate and high powered options are available.

What are the limitations of acoustic hearing aids? They can only amplify a small frequency range (relative to the normal cochlea); they offer only minimal improvement in frequency resolution; they are unable to improve temporal resolution associated with cochlear hair cell damage; background noise remains a problem and there may also be acoustic feedback for patients with severe/profound HL.

What can be offered to patients when hearing aids provide only a limited solution to rectifying HL?

Dr O'Driscoll mentioned (i) *Bone Conduction Devices (BCD)* which are anchored to bone either percutaneously or transcutaneously and are more suitable for conductive hearing losses; (ii) Acoustic devices i.e., *middle ear implants* (MEI) which are hearing aids that are implanted into the middle ear and (iii) Electrical devices, i.e., cochlear implants (CI) and auditory brainstem implants (ABI).

(i) The *percutaneous BCD* employs osseointegration with the device surgically implanted in the bone behind the ear. These can be appropriate from aged five upwards and cost about £4,000. They can be bilateral or single–sided and may be appropriate for a range of medical conditions. They are mainly used to help people with conductive hearing losses.

The *transcutaneous BCD* is available as the BONEBRIDGE which uses a bone vibrator that is positioned under the skin in the bone behind the ear. This is fully implanted and powered through an external transducer that is held in place on the scalp magnetically over the fully implanted bone vibrator. The BONEBRIDGE device is for conductive and mixed HL and may be appropriate for patients older than five years. The cost is approximately £8,000.

(ii) For Middle Ear Implants, Dr O'Driscoll described the SOUNDBRIDGE and CARINA devices. These are similar in that each generates electrical signals to an internal transducer that is implanted onto the bones in the middle ear and produces mechanical vibrations that are sent directly to the inner ear. The SOUNDBRIDGE device has an external microphone that is held in place magnetically behind the ear and links to the inner electronics package. The CARINA device differs in that it has an internally implanted microphone and is the first fully implantable hearing system. For these implantable hearing aids, the patient must have a stable HL for more than two years. They can be funded by the NHS for patients who are unable to wear conventional hearing aids and they cost about £8,000.

(iii) Dr O'Driscoll turned to electrical implants which are suitable where the hearing loss is too great to gain benefit from hearing aids. The most common electrical implant is the *cochlear implant (CI).* He gave a detailed description of how a CI works. There is a sound processor worn by the patient over the ear and this part of the device receives airborne sound waves and turns them into an electrical digital code. This sound processor has a battery that powers the entire system. The patient also wears a transmitter coil on the outside of the head, above and behind the ear, and this part receives the signals from the sound processor. This, in turn, transmits a radio signal through the skin to an implanted internal receiver. The internal receiver presents an electrical signal via a wire to an electrode array which has been implanted directly in the inner ear (cochlea).

This electrode array that has been implanted into the cochlea consists of individual electrodes, each of which stimulates to different frequencies. The electrodes that are positioned further into the cochlea will give perception of a low pitch sound when they stimulate the auditory nerve fibres. The electrodes that are positioned close to the entrance of the cochlear will give a perception of a high pitch sound when they stimulate the auditory nerve fibres. This is taking advantage of the natural tonotopicity (frequency mapping) of the cochlea.

Dr O'Driscoll noted that world-wide, there are four main manufacturers of cochlear implants (Advanced Bionics, MEDEL, Cochlear & Oticom Medical).

Dr O'Driscoll gave the audience a detailed assessment of the use of cochlear implants. He cited the NICE Guidelines for eligibility for cochlear implantation. (www.nice.org.uk/guidance/TA566).

The *audiological criteria* for cochlear implant eligibility are bilateral severe to profound hearing loss with thresholds ≥ 80 dB at any two frequencies between 500 Hz and 4 kHz. These latest NICE criteria relax the old criteria (previously, ≥ 95 dB at 2 kHz and 4kHz).

The current *speech perception criteria* are "A phoneme score of 50% or greater on a monosyllabic word test presented at 70 dBA".

If a patient falls within these guidelines, the NHS would fully fund the procedure in respect of (i) adult unilateral CI (but bilateral if severely visually impaired) and (ii) children and adolescents bilateral CI (if clinically appropriate). The cost of a cochlear implant device is about £16,000.

How well do cochlear implants work? Dr O'Driscoll answered this question with reference to two bar charts.

Pre-implant, a typical adult with hearing aids will score about 10% correct words in a speech test presented at 70dB in quiet but, after one week of cochlear implant use, the score increased to 52%. At three months, these figures rise to 76%. After nine months, the benefit further increases to 85%, demonstrating how effective hearing with a cochlear implant can be compared with hearing aids for severe to profoundly deaf patients

For children, quantifying the improvement is complex due to the chronological and language ages of the child but a marked improvement in the difference between the chronological age and language age is evident over the first couple of years of implant use.

Do we have any predictors of outcomes with CI?

For adults, the shorter the duration of deafness before the CI, the better the outcome. Pre-lingually deafened adults, who have not developed clear spoken language or who are primarily users of sign language generally have a poor outcome with a CI and, for these patients, CI would not be usually offered.

As regards children, for those who are congenitally deaf, early implementation is better as this takes advantage of cortical plasticity. Children who are implanted before the age of two, can expect age appropriate speech and language development by the time they reach five years if given appropriate support.

The practice in Manchester is to have a cut-off age of four years for congenitally deaf children. Dr O'Driscoll stressed that most children with congenital deafness in the UK are diagnosed at birth through newborn hearing screening and have their implant before the age of two.

Continuing the theme of electrical implants, Dr O'Driscoll moved on to talk about the clinical situation when the hearing nerve is damaged or absent. The main causes of this condition in adults is neurofibromatosis, type 2 which can affect 1 in 35,000 and results from a defect in chromosome 22. It is characterised by bilateral benign tumours vestibular schwannoma on the hearing nerves and ultimately leads to profound bilateral hearing loss. For these patients, hearing aids and cochlear implants offer no benefit but an auditory brainstem implant (ABI) is an option.

Another cause of this condition in children is congenital cochlear nerve deficiency. The incidence of this is unknown. The clinical diagnosis requires an MRI scan and, as with neurofibromatosis type 2, there is no benefit from hearing aids or a cochlear implant as the hearing nerve is absent of malformed- for these children an ABI is usually the only option for hearing.

The ABI is similar to a cochlear implant but the electrode is not positioned in the cochlea but is located over the cochlear nucleus of the brainstem at the location where the hearing nerve (if it was present) enters the brain stem.

Moving away from clinical studies, Dr O'Driscoll displayed a map of the cochlear implant centres in the UK. His map showed seventeen centres in England (with four in Wales, two on the island of Ireland and one in Scotland). Apart from Manchester, the nearest centre locally is at Glan Clwyd Hospital in north Wales.

How many patients are maintained with cochlear implants in the UK? For the year ending 31 March, 2019, the national number is 18,490. Data from the British Cochlear Implant Group has 11,477 (adults, unilateral); 864 (adults, bilateral); 1,868 (children, unilateral) and 4,281 (children, bilateral).

For Manchester, the totals number of patients to date are 1,390 adults (implanted since 1988) and 1,049 children (implanted since 1992).

To end his talk, Dr O'Driscoll gave a vision of the future! Connectivity via wireless technology is here. Telemedicine, smartphone apps, Bluetooth streaming, artificial intelligence.

Dr O'Driscoll ended his talk with a video showing the world's first multi-purpose intelligent hearing aid. How does it work? The patient requests assistance via the app on their smartphone. The hearing care professional receives this request via the Cloud. The professional responds back to the patient, again via the Cloud, and sends updated settings and any messages. The patient receives this update and any messages. The process of request by patient → response by hearing care professional → receiving this response by the patient is remote and the whole process happens without meeting.

Dr Harold Stockdale (IOP Merseyside) warmly applauded the presentation. He commented on the informed and very listenable presentation which had kept the audience's attention.

Dr Stockdale invited questions from the audience and that the question time had to be ended at 8.00pm indicated the audience's level of interest. Dr Stockdale led the vote of thanks to Dr O'Driscoll in the usual manner.

Harold Stockdale