The future of treatments for hearing and balance: a 15 and 50-year perspective

BY JAMEEL MUZAFFAR AND MANOHAR BANCE

Jameel Muzaffar and **Manohar Bance** paint a picture of what otology will look like 15 and 50 years' time. Will we still need doctors? Will there still be an ENT news journal?

The last 50 years have seen advances including the widespread adoption of the operating microscope and, more recently, auditory implants and endoscopic ear surgery. The next 15 years offer the promise of ever more rapid progress based on improved understanding of the mechanisms of hearing and balance impairment and novel approaches to their treatment.

What can we expect in the next 15 years?

Auditory implants

It is now just over 50 years since the first cochlear implant was pioneered by Clark, Hochmair, Blake and House in the late 1950s and early 1960s. Few would argue against the life-changing impact of these devices for patients with profound hearing loss or cochlear implantation's status as the most successful human neuroprosthesis. However, such devices have a number of limitations, including risks such as the loss of residual hearing, facial nerve paralysis and increased risk of meningitis. Moreover, they provide limited pitch perception and limited ability to appreciate music; additionally the external components are not suitable for swimming or water sports and may cause social stigma. We are likely to see a continuation of the trend towards increased integration with external peripherals, such as mobile phones and the internet and self-programming of devices based on neural responses, especially in children. Devices already in development include microphones concealed under the skin or positioned in the mastoid or middle ear. With improving battery technology, miniaturisation and novel arrays implanted directly into the auditory nerve devices of the next 15 years are likely to overcome many of today's limitations. The use of robotic assistance to insert arrays and monitor their positon holds the promise of less surgical trauma and therefore improved preservation of residual hearing. Ongoing efforts to improve plasticity of the auditory cortex promise improved outcomes in long-deafened adults. Vestibular implants and improvements in balance rehabilitation technologies hold much promise for an ageing and increasingly multi-morbid population.

Regenerative medicine

Regenerative therapies for the inner ear are currently in a similar position to those of the eye around 10 to 15 years ago. A number of promising pharmacological and cellular options are now in early human trials with many more to follow. This revolution has been based on improved understanding of the underlying mechanisms similar to those that drove revolutions in ophthalmology. A number of these are otoprotective, for example to mitigate the effects of aminoglycosides or chemotherapeutic agents with some of the most interesting focused on regeneration of specific anatomical locations within the inner ear. A great example of a potential therapeutic group is the gamma secretase inhibitors which reduce Notch signalling, allowing the differentiation of cochlear supporting cells into new sensory hair cells. Gamma secretase inhibitors are being investigated in the European Commission funded REGAIN trial. This study is running across the UK, Germany, The Netherlands, Denmark and Greece highlighting the potential importance of decentralised research and the development of the networks needed to realise this. Therapeutic options like this represent a shift away from our current model, based entirely on prosthetics such as hearing aids and auditory implants, to repair of natural biological structures. The greatest challenge to this is currently our limited ability to accurately identify the location of lesion within the auditory pathway. Without this we are unable to optimise design and recruitment to appropriate clinical studies or to target therapies in patients that would benefit most from them once they are widely available. Efforts to identify such sites of lesion are a core part of the author's own research activities. Such approaches may also allow regeneration of middle ear mucosa, a potential treatment approach for chronic middle ear disease, a particularly significant problem in the developing world. Non-regenerative pharmacological treatments may provide support for vulnerable structures, such as the stria vascularis, for which our understanding is incomplete and therapeutic options currently lacking.

Telemedicine and clinical assessment

The overwhelming majority of innovation is focused on applications for the developed world. One area where resource poor settings stand to gain as much or more is the use of telemedicine approaches, potentially combined with machine learning technologies to reduce the

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requirement for costly input from doctors. Telemedicine approaches for audiology are not a new idea, with academic studies appearing from the late 1990s. However, the near ubiquity of internet access, often via mobile devices, makes this an increasingly feasible option. Even in affluent countries, the increasing age of the population, combined with the demand for more rapid access to input and treatment, will accelerate the move towards remote assessment and management. A major trend will be towards point of symptom diagnostics with objective recordings in the patient's own home with real-world data logging and continuous adjustment. We also expect to see a continuation of the trend towards the use of rigid endoscopes as an alternative to traditional otoscope in an outpatient setting along with increased utilisation of the endoscope as a tool in the otologist's operative repertoire; though the bimanual advantages of the operating microscope will ensure it has a role for the foreseeable future. Clinical assessment in the outpatient setting is likely to make more use of novel technology for objective assessment of balance and a shift away from reliance of pure tone audiometry to include tests of hearing more reflective of real world performance.

What can we expect in the next 50 years?

Whilst it is not difficult to envisage totally implantable cochlear implants or regenerative therapies for the inner ear within the next 15 years, the next 50 years are more difficult to predict. Advances in our understanding of the genetic basis of hearing and balance impairment will initially allow better counselling of risk, and later gene, editing. Regenerative therapies may render operative interventions redundant and genetic profiling may allow diseases to be identified and risk modified long before they manifest clinically. The use of surgical robotics may remove the human component entirely from the operative process long before this.

Artificial intelligence and the use of Big Data will help to shape and inform clinician and patient decision-making. There has been some controversy over whether these technologies may render doctors redundant but it is the authors' view that nothing can entirely replace the human-human interaction.

One of the most intriguing challenges of the next 50 years will be to provide hearing and balance capabilities beyond that provided by nature. This may come through novel neural prostheses with supplementary processing capabilities. Such devices may not only help to overcome limitations like the 'cocktail party effect', where patients particularly struggle understanding speech in background noise, but allow access to parts of the frequency spectrum not normally heard by humans.

Conclusion

As the gradient of change in this area has become steeper, the next 15 years promise much more rapid change than we've seen in the previous 15, based on improved understanding of the mechanisms of disease and novel therapies and technology.

The key areas are already being explored in research studies and include advances in auditory implants, telemedicine approaches and regenerative therapies delivered to the inner ear. The next 50 years will see a transition away from treatment of clinically delineated disease to preventative approaches based on genetics and Big Data. The continued merging of humans and machines may change the paradigm to provision of hearing and balance capabilities beyond our biological limits as devices become equal to, and eventually surpass those, of nature.

FURTHER READING

- www.masseyeandear.org/news/press-releases/2015/05/2015-future-directions-cochlear-implants
- https://theconversation.com/cochlear-implant-creator-honoured-with-top-us-prize-18186
- www.bmj.com/content/363/bmj.k4563
- www.youtube.com/watch?v=EJ_9plDI4N8
- https://twitter.com/berci
- www.regainyourhearing.eu

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