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Cochlear Implant and Its Future

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The auditory system is one of the basic sensory systems for humans. Humans can perceive sound waves and interpret them into meaningful words and approximately localize where the sounds come from because of the auditory system. Human can hear the sound because the sound waves travel into the ear through ear canal to eardrum. The eardrum passes the vibrations through the middle ear bones or ossicles into the inner ear. The inner ear is also called the cochlea, and inside the cochlea, there are thousands of tiny hair cells. The outer hair cells (OHCs) provide active, non-linear amplification of the sounds, whereas inner hair cells (IHCs) passively respond to cochlear mechanics (Allen, 1980). Those hair cells change the vibrations into electrical signals that are sent to the brain through the auditory nerve. The auditory cortex is part of cerebral cortex to receive those auditory inputs, and it is part of auditory system that performing basic and higher functions in hearing (Cf. Pickles, James O, 2012).

Listening to music is a wonderful pastime for human, but what happen to those people who are congenital deaf or suffered from hearing loss because of disease. Deafness and hearing loss can not only impair those people from hearing the music, but also impact their daily life both physically and mentally (Andrea et al., 2012). Cochlear implant is one of the solutions for those people to enjoy the music and get back to normal life. Based on the definition from FDA (2014), "A cochlear implant is an implanted electronic hearing device, designed to produce useful

hearing sensations to a person with severe to profound nerve deafness by electrically stimulating nerves inside the inner ear“. There are two parts for a cochlear implant, an internal part called the internal implant and an external part called a speech processor (Cliff. A. Megerian, 2015). As shown in figure 1, the speech processor uses small microphones to collect sounds and turns those sounds into signals that is then sent to a transmitter. Through the skin, signals are transmitted to the internal implant. The internal implant first converts the signals into electrical energy, and then sends them to electrode array. Electrode array receives the electrical energy and stimulates the auditory nerve, which finally sends signals to brain. Unlike hearing aids, which simply make sound louder, cochlear implant is put to facilitate hearing. Its intended purpose is to help people with hearing loss who do not benefit from hearing aid.

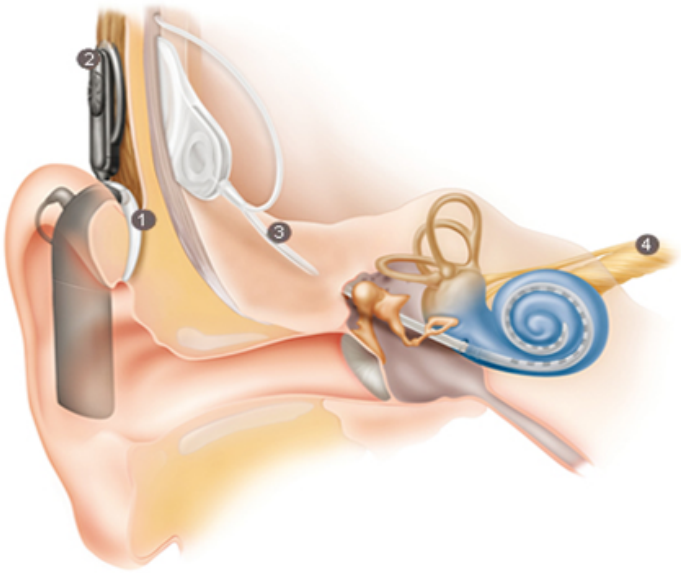

Figure 1. 1 is speech processor. 2 is transmitter. 3 is internal implant. 4 is auditory nerve. The electrode array is placed inside the cochlear (blue area). This figure is originally from webpage of cochlear.com (Cochlear.com, n.d.). Available at http://www.cochlear.com/wps/wcm/connect/au/home/understand/hearing-and-hl/hl-treatments/cochlear-implant

A cochlear implant usually helps people with profound sensorineural hearing loss, or nerve deafness, those types of loss often involves damage to the outer hair cells (OHCs) and inner hair cells (IHCs) (Brian C. J. Moore, 1995). Research by Joseph B. Nadol (1993) indicates that synapses with approximately 90% of the primary auditory neurons are formed by hair cells, which also helped to transduce most auditory information. When those hair cells are damaged, sound will never reach the auditory nerve, which means brain cannot receive any signals. But the cochlear implant can skip the damaged hair cells and sends signals to the auditory nerve directly, because the electrode array can stimulate the auditory nerve instead of the damaged hair cells. A research result showed that adults who had been using cochlear implants for 6 months had a better average score on speech recognition than people who had been using hearing aid (Trail result, 2008). This hybrid system, which is the mixture of hearing implants with auditory system, can not only help with adults, but also play an important role for children. It can improve hearing performance and oral communication for children. According to the study from Ana Cristina Coelho (2016), children with cochlear implants achieve stronger auditory perception and better speech intelligibility. However, there were still significant differences between children with normal hearing and those with cochlear implants for language skills (Zahra Soleymani, Najmeh Mahmoodabadi, Mina Mohammadi Nouri, 2016).

This merged system was an intentional outcome of the introduction of the hearing implants to the human auditory system. The benefits of creation this system are that people who are deaf or suffered from hearing loss can hear the sound, they can feel safer in the world, and they can talk on the phone or even listen to music to some extent. The downsides of this system are MRI incompatibility, risks during surgery, and the price of cochlear implant products are expensive, the quality may vary from products to products, and people who have cochlear

implants may hear the word differently, may lose their residual hearing and they may have to change their lifestyle to adapt to the device. A study from Rob and David (1999) has showed that for profoundly deafened adults, their health-related quality of life increased from 11% to 37% in Australia because of the hearing implants. And the results of that study "give a strong indication that it is an effective technology that is acceptable value for money in Australia" (Rob Carter, David Hailey, 1999).

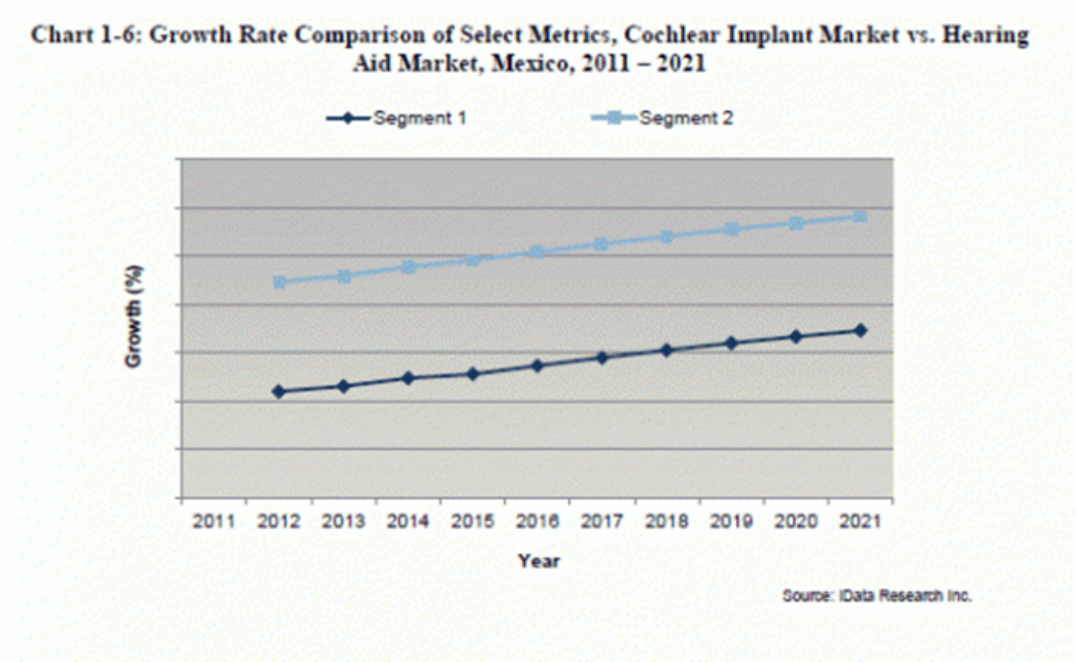

Figure 2. The growth rate for cochlear implant market vs. hearing aid market in Mexico, 2011-2021.
Segment 1 represents hearing aid market, and segment 2 represent cochlear implant market. This figure is originally from iData Research (iData Research, 2014). Available at http://www.giiresearch.com/report/ida322308-mexican-market-hearing-devices-batteries.html

That being the case, there are reasons to believe that the market for hearing implants around the world will be booming in the next few years. Based on figure 2, the expected growth rate for cochlear implant market in Mexico is much higher than the growth rate for hearing aid market from 2011 to 2021 (iData Research, 2014). The future of this hybrid system is bright. There will be more and more cochlear implants with different functions hybrid with human auditory system. And the hybrid system in the future will not only allow people with hearing loss to hear again, but also enhance human hearing, such as an ability to hear long-distance voice and an ability to only focus on specific sound in noisy environments. With the advance in technology, those multifunctional cochlear implants will be commercialized in the next few years.

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I have abided Wheaton College Honor Code in this work--Guanjia Pan