Treating Hearing Loss Through Invasive and Noninvasive Stimulation Technologies

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Over the past decade, there have been rapid developments in novel neural technologies for treating a wide range of neurological and health disorders, catalyzed by the large increase in funding provided through NIH BRAIN Initiative, DARPA and other funding mechanisms. Invasive and noninvasive technologies have been pursued by multiple groups, in addition to different energy modalities including electrical, magnetic, optical and ultrasound stimulation. One major goal of my lab has been to treat hearing loss and enhance communication capabilities with new invasive and noninvasive electrical stimulation technologies.

For hearing restoration, cochlear implants have enabled hundreds of thousands of deaf individuals to hear and better integrate into mainstream society. The cochlear implant is considered one of the most successful neural prostheses. However, there are deaf individuals who cannot benefit from a cochlear implant, which requires implantation into the cochlea and electrical activation of the auditory nerve. These individuals include those without functional auditory nerves (e.g., due to removal of tumors that compromises their nerves) or ossified cochleas not allowing for an electrode array to be inserted into the cochlea. In my lab, we are pushing the development of two new central auditory implants. One device is designed to be implanted into the auditory midbrain (inferior colliculus) for those without a functional auditory nerve. This auditory midbrain implant (AMI) consists of two linear electrode arrays with 11 sites each that is inserted into the inferior colliculus with sites located in different frequency regions. The AMI evolved from extensive animal experiments and safety studies that transitioned into a clinical trial funded by NIH with the goal to implant up to five deaf patients. The device was developed together with Cochlear Limited (Australia). The other hearing device is designed to be implanted into the auditory nerve for those who cannot be implanted into the cochlea but still have a functional auditory nerve. This auditory nerve implant (ANI) leverages the Blackrock (Utah) electrode array technology in which a customized high-density array (e.g., with 6x9 shanks) is being developed and connected with a MED-EL stimulator (Austria) for implantation in up to 3 deaf patients. Both the ANI and AMI are initially intended to provide hearing solutions to those who cannot sufficiently benefit from cochlear implants. However, success through these initial clinical studies could open up future opportunities for the ANI or AMI to provide improved hearing compared to cochlear implants, since the electrode arrays are directly interfacing with the auditory neurons and could enable a greater number of independent channels of auditory information to the brain (i.e., they would not be limited by the bony cochlear wall that blocks and smears the electrical current attempting to reach the auditory nerve as occurs for cochlear implants). Ongoing developments for these different neural technologies will be presented with future directions for how these technologies can enable a paradigm shift in the hearing treatment field as well as provide new treatment opportunities for other clinical applications.

Looking beyond the horizon of implantable neural technologies, one exciting stimulation approach has begun to emerge for noninvasively modulating the brain and various sensory and motor neural pathways – ultrasound neuromodulation. Current research will be briefly summarized for this emerging field of ultrasound neuromodulation and future opportunities will be presented in how this stimulation approach can be used for treating hearing loss. In particular, my lab has identified ultrasound stimulation parameters that can modulate brain activity in sensory cortices as well as noninvasively activate the peripheral hearing system. We are also developing wearable ultrasound technologies with a start-up medical device company for various neuromodulation and health applications. However, there are still multiple challenges in understanding the mechanism(s) of activation of ultrasound and in optimizing stimulus parameters that can effectively and safely stimulate the head and nervous system for long-term use in humans. It is still early days for ultrasound neuromodulation but the optimism and opportunities surrounding this new stimulation approach is inspiring for the neural engineering field towards reaching the holy grail of neurostimulation: noninvasive and targeted activation of the nervous system.