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History of Cochlear Implants and Auditory Brainstem Implants

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Abstract

Cochlear implants have evolved during the past 30 years from the single-electrode device introduced by Dr. William House, to the multi-electrode devices with complex digital signal processing that are in use now. This paper describes the history of the development of cochlear implants and auditory brainstem implants (ABIs). The designs of modern cochlear and auditory brainstem implants are described, and the different strategies of signal processing that are in use in these devices are discussed. The primary purpose of cochlear implants was to provide sound awareness in deaf individuals. Modern cochlear implants provide much more, including good speech comprehension, and even allow conversing on the telephone. ABIs that stimulate the cochlear nucleus were originally used only in patients with neurofibromatosis type 2 who had lost hearing due to removal of bilateral vestibular schwannoma. In such patients, ABIs provided sound awareness and some discrimination of speech. Recently, similar degrees of speech discrimination as achieved with cochlear implants have been obtained when ABIs were used in patients who had lost function of their auditory nerve on both sides for other reasons such as trauma and atresia of the internal auditory meatus.

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Cochlear Implants

When Dr. William House [1] first introduced the cochlear implant it was met with great skepticism. Pioneering work by Michaelson regarding stimulation of the cochlea preceded the first clinical application of this technique [2]. While the success of modern multichannel cochlear implants is a result of technological developments, this success would not have been achieved, at least not as rapidly, if brave individuals such as Dr. House had not taken the bold step to try to provide some form of hearing sensations for individuals who were deaf because of injuries to cochlear hair cells.

Published studies of electrical stimulation of the auditory nerve date back half a century when Djourno and Eyries [3] described how electrical current passed through the auditory nerve in an individual with a deaf ear could cause sound sensation although only noise of cricket-like sounds. Later, Simmons et al. [4] showed that electrical stimulation of the intracranial portion of the auditory nerve using a bipolar stimulating electrode could produce a sensation of sound and some discrimination of the pitch of the stimulus impulses below 1,000 pulses per second (pps) with a difference limen of 5 pps. Above 1,000 pps, the discrimination of pitch was absent but the participant in the test could distinguish between rising and falling pulse rates.

The earliest cochlear implants used a single electrode placed inside the cochlea [1]. Introduction of cochlear implants that use multiple implanted electrodes and better processing of the signals from the microphone provided major improvements in speech discrimination. Using more than one electrode made it possible to stimulate different parts of the cochlea and thereby different populations of auditory nerve fibers with electrical signals derived from different frequency bands of sounds. Now, all contemporary cochlear implants separate the sound spectrum using bandpass filters so that the different electrodes are activated by different parts of the sound spectrum [5]. When such more sophisticated processing of sound was added the results were clearly astonishing, and modern cochlear implants can provide speech discrimination under normal environmental conditions [6]. Even those individuals who had great expectations were surprised by these accomplishments.

Sound Processing in Cochlear Implants

All modern cochlear implant devices process sounds and these processors have contributed greatly to the success of cochlear implants and auditory brainstem implants (ABIs). The advent of fast microprocessors, similar to what is found in personal computers, has made it possible to perform sophisticated signal processing of the sounds that are picked up by a microphone. Processors of modern cochlear and brainstem implants operate on the sounds picked up by the wearer's microphone. Refining the way the processors work and especially the algorithms used that has occurred during past one or two decades has contributed considerably to the success of cochlear implants. These processors have undergone many stages in their evolution since Dr. House introduced the first cochlear implants.

The processors of the first cochlear implants converted sound into a high-frequency signal that was applied to a single electrode in the cochlea. Contemporary cochlear implants have an array of several electrodes implanted

