A Brief History of Cochlear Implants

While commercial cochlear implant systems have only been available since the 1980s, the idea of using electrical rather than acoustic stimulation to activate the auditory system in individuals with profound sensorineural hearing loss is not new.

In 1880, Alessandro Volta first reported that electrical stimulation to metal rods inserted in his ear canal created an auditory sensation. He described this sensation as "a boom within the head."

In 1957, Djourno and Eyries placed a wire on the auditory nerve of someone who was undergoing surgery. They used this wire to stimulate the auditory nerve directly with electrical current and the person reported a clear auditory percept. This observation lent to the search for a treatment of profound deafness.

In 1961, House and Doyle reported data from two adults with profound deafness whose auditory nerve was stimulated electrically by an electrode placed on and then through the round window and into the scala tympani of the inner ear. These individuals both reported auditory percepts. They noted that loudness changed with level of stimulation and the pitch of the stimulus changed with variation in the rate of stimulation.

In 1964, Simmons placed an electrode through the promontory into the vestibule and directly onto the modiolus of the cochlea. Again, these individuals could detect changes in duration and had the percept of tonality. These observations fueled the push toward the development of functional, permanent CI systems.

The first single channel cochlear implant was introduced in 1972. Over 1000 people were implanted from 1972 to the mid 1980s including several hundred children.

Introduction

According to the National Institute on Deafness and Other Communication Disorders (NIDCD), "A cochlear implant is a small, complex, electronic device that can help to provide a sense of sound to a person who is profoundly deaf or severely hard of hearing."

Cochlear implants are electronic devices that contain a current source and an electrode array that is implanted into the cochlea; electrical current is then used to stimulate the surviving auditory nerve fibers. When a person decides to get a cochlear implant, they virtually decide to take the oral education route. Sign language can be used but the auditory stimuli he/she will be receiving will push him/her into eventually vocalizing and speaking.

Even though someone may be deaf and their hair cells destroyed, the ear can still do some things to aid in the hearing process. So when a cochlear implant is used, it builds on the useful parts of the hearing mechanism and puts them to work.

Even though various manufactures make cochlear implants just a little different from each other, there are still five basic components of the implants:

The externally worn, non-implanted components of the device include:

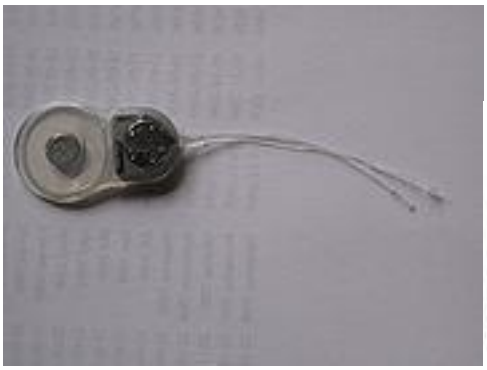
1) The microphone; it is located on the outside of the head and it collects sounds from the environment to be heard.

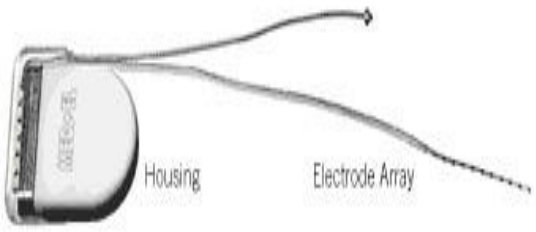
2) The speech processor; it is also outside the body and it uses digital signal processing to decipher the sounds collected by the microphone. It can be worn on the body (similar to a body worn hearing aid) or behind the ear (similar to a BTE hearing aid).

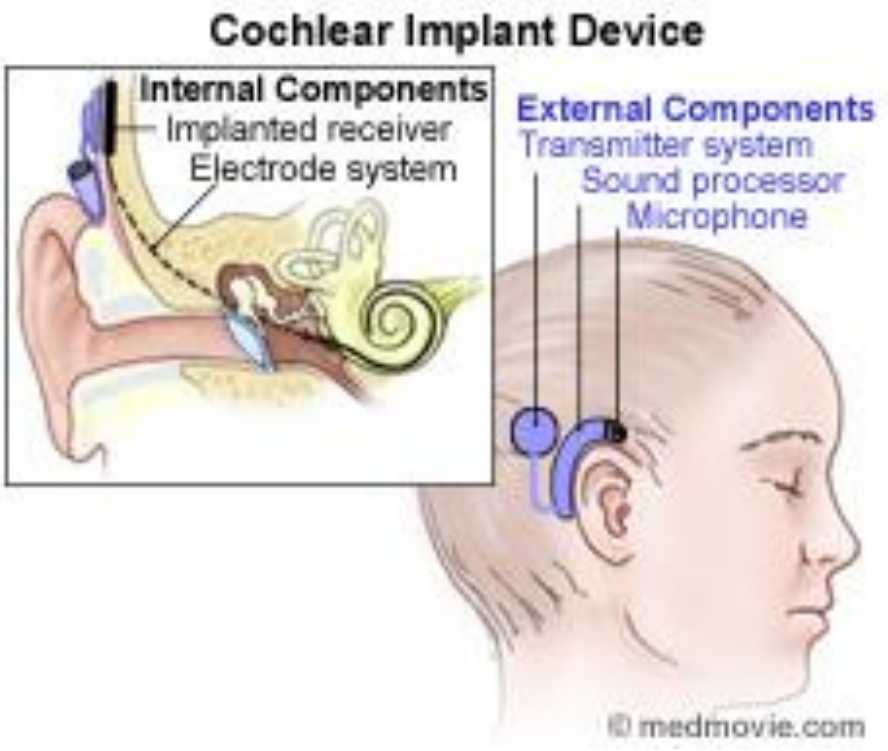
3) The transmitter, or outer coil, is placed on the mastoid (usually held in place by magnets) it receives the signals from the amplifier and sends the processed signal to the receiver via radiofrequency.

The surgically implanted components include:

4) The receiver, or stimulator is housed in a bio-compatible case, which is surgically implanted under the skin behind the ear(over the mastoid), and it contains a magnet, which couples to the magnet in the transmitter worn externally. It receives the signal and sends electrical energy to one or many electrodes in the array.
5) The electrodes; they receive the transmitted signals from the transmitter and send them up to the auditory nerve so that the brain can receive them and interpret the sounds.







Surgery

The device is surgically implanted under a general anaesthetic, and the operation usually takes from 1½ to 5 hours. First a small area of the scalp directly behind the ear is shaven and cleaned. Then a small incision is made in the skin just behind the ear and the surgeon drills into the mastoid bone and the inner ear where the electrode array is inserted into the cochlea. The electrode arrays are inserted into the scala tympani of the cochlea via an opening (cochleostomy) that is surgically created just lateral to the round window.

The cochlear implant systems uses transcutaneous communication between the externally worn hardware and the implanted electronic components. No wires or other electronic components pass through the skin barrier.

The patient normally goes home the same day as or the day after the surgery, although some cochlear implant recipients stay in the hospital for 1 to 2 days. It is considered outpatient surgery.

Risk

As with every medical procedure, the surgery involves a certain amount of risk; in this case, the risks include skin infection, onset of tinnitus, damage to the

vestibular system, and damage to facial nerves that can cause muscle weakness, impaired facial sensation, or, in the worst cases, disfiguring facial paralysis.

There is also the risk of device failure, usually where the incision does not heal properly. This occurs in 2% of cases and the device must be removed.

The operation also destroys any residual hearing the patient may have in the implanted ear; as a result, some doctors advise single ear implantation, saving the other ear in case a biological treatment becomes available in the future.

In 2003, the FDA announced that children with cochlear implants are at a slightly increased risk of bacterial meningitis. Though this risk is very small, it is still 30 times higher than children in the general population, without proper immunizations. The national health organisations (such as the UK) now follow the practice of providing prophylactic vaccination against pneumococcal meningitis.

The implant has a few effects unrelated to hearing. The external components must be turned off and removed prior to swimming or showering. Some brands of cochlear implant are unsafe in areas with strong magnetic fields, and thus cannot be used with certain diagnostic tests such as magnetic resonance imaging (MRI), but some are now FDA approved for use with certain strengths of MRI machine. Large amounts of static electricity can cause the device's memory to reset. For this reason, children with cochlear implants are also advised to avoid plastic playground slides.

Types of Cochlear Implants

Cochlear implants can be distinguished by their use of single vs. multiple channels, and the number of electrodes. The number of electrodes stimulated with different electrical stimuli determines the “channels” used. In other words, an implant may have multiple electrodes, but if the same information is presented to all the electrodes at one time they are essentially functioning as a single channel system.

In contrast, multi-channel devices provide different information to several electrodes or groups of electrodes. Early implants had only one electrode (and one channel); recent advances have lead to the development of implants with multiple electrodes up to 22 and multiple channels usually 4-8. Having more electrodes means that multiple channels can be localized to areas of the cochlea that are most responsive, and stray current that is stimulating adjacent structures (facial nerve, vestibular nerve) can be rerouted.

A great deal of research has been dedicated to improving the design of the implant system, identifying the best intracochlear array and stimulation mode, refining the processing strategies available and miniaturizing both the external and internal hardware. Currently there are three FDA approved, multichannel CI systems available within the United States. These include the Nucleus Cochlear Implant System marketed by Cochlear Corporation, the Clarion device marketed by Advanced Bionics Corporation, and the Med-El device marketed by Medical Electronics Corporation.

Cochlear Implant Candidacy

Cochlear implantation has been an approved method of treating profound, bilateral, sensorineural hearing loss for persons since the mid-1980s.

Along with advances in engineering and speech processor design have come changes in the criteria for cochlear implant candidacy. For example, initially only adults with postlingual profound deafness were considered suitable candidates for cochlear implantation; now, audiometric thresholds are no longer a primary determinant of cochlear implant candidacy for postlingually deafened adults.

Now, adult criteria include bilateral severe-to-profound sensorineural hearing loss with 70 dB pure tone average, little or no benefit from hearing aids (must attempt binaural high-powered hearing aids for at least 6 months), and psychological suitability. Audiologic examination should show word discrimination scores less than 40% in the best aided condition. The patient should have no anatomical deformity that would preclude implantation success. Finally, the patient should have no physical condition that would preclude a general anesthetic.

Similarly, congenitally deaf children initially were not considered suitable candidates for multichannel cochlear implantation. When implantation of children was approved by the FDA it was limited to children 2 years of age and up; now, the FDA has approved the use of multichannel cochlear implants in prelingually deafened children as young as 12 months of age, and many children younger than 12 months of age have been implanted off protocol.

Pediatric implantation is indicated in children 12 months or older with bilateral severe-to-profound sensorineural hearing loss with pure tone averages of 90 dB or greater in the better ear. The child must have had no appreciable benefit with hearing aids evaluated with parental survey when younger than 5 and 30% or less on sentence recognition tests under best-aided conditions when 5 years old or older.

Contraindications for Cochlear Implantation

Not all patients with sensorineural hearing loss are good candidates for cochlear implantation. The absence of the cochlea (Michel deformity), and a small internal auditory canal (associated with cochlear nerve atresia) are contraindications to implantation on that side.

The presence of active middle ear disease is a contraindication to surgery. This process should be treated and resolved before implantation.

Adults and children with acute meningitis should be treated with steroids to avoid hearing loss. Those that do sustain hearing loss secondary to meningitis should be observed before implantation due to the substantial number of patients that will regain their hearing in at least one ear.

A diagnosis of mental retardation, psychosis, and unrealistic expectations may also be contraindications.

Therapy

After 1–4 weeks of healing (the wait is usually longer for children than adults) during which the wound must be kept dry, the implant is turned on or "activated".

Results are typically not immediate, and post-implantation therapy is required as well as time for the brain to adapt to hearing new sounds. Audiological training and speech therapy typically continue for years, though infants can become age appropriate - able to speak and understand at the same level as a hearing child of the same age in a matter of months; however it is far more common for the process to take years.

Programming the speech processor of the cochlear implant typically requires establishing a threshold and a maximum stimulation level for each of the individual intracochlear electrodes. These levels are customized for the individual user and need to be adjusted several times for most individuals during the first year or so of cochlear implant use and less frequently thereafter.

The externally worn speech processor can be programmed to allow the user to select from a range of programs and/or programming strategies. This flexibility allows the user to evaluate different programming strategies in a range of real world listening conditions. For pediatric applications, it can allow the parents to work through a set of programs with progressively more intense outputs or

wider dynamic ranges as the child accommodates to auditory stimulation. Because speech processor programs are customized for an individual user, speech processors set for one individual should never be placed on any other cochlear implant recipient.

The participation of the child's family in working on spoken language development is considered to be even more important than therapy, because the family can aid development by participating actively and continually in the child's therapy, making hearing and listening interesting, talking about objects and actions, and encouraging the child to make sounds and form words.

Average Performance

Average performance has improved significantly over the course of the past decade. It is no longer just the “star” performers who enjoy open set word recognition. The best cochlear implant users now achieve sound only word recognition scores of 80% or higher regardless of device. However, not all cochlear implant users enjoy such high levels of performance.

Some recipients of CI obtain limited open set word recognition. One of the largest challenges facing cochlear implant professionals is to find preimplant predictors of postimplant performance. Moreover, finding ways to improve performance for individual cochlear implant users remains a challenge.

Patient Counseling and Expectations

Candidates for cochlear implantation come for evaluation with all levels of knowledge about cochlear implants and need to be informed of the potential risks and benefits of cochlear implantation and the impact it may have on their life. The surgical procedure and its risks should be described along with a physical description and, preferably demonstration, of the internal and external portions of the device. The various cochlear implant systems available at the center also should be shown and described to the candidate. The post-surgical programming commitment should be described and planned. In addition, potential cochlear implant candidates need to be aware of what day-to-day living with the device entails. This is best done by contacting other cochlear implant wearers and their families.

The most important, yet sometimes difficult, aspect of patient counseling is generating realistic expectations regarding performance outcome with the implant. Almost all candidates or their families seek the implant because they want to improve their ability to hear and understand speech.

Although the mean and range of performance with implants can be described, most people will naturally hope for the best of outcomes. Redundantly reviewing the range of performance, including the bottom of the range, during the course of the candidacy evaluation and discussing post-implant plans in case performance with an implant is poorer than anticipated can assist those recipients who obtain minimal postimplant benefit.