Major Breakthroughs in Cochlear Implant

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Abstract— It is estimated that 250 million people have disabling hearing impairment, i.e. moderate to severe hearing loss, representing 4.3% of the world's population. When only the middle ear is affected, but not severely, a simple amplifying hearing aid is enough to overcome the problem. If the middle ear is totally destroyed or there is a loss of hair cells from the cochlea, but the auditory nerve is still intact, then a cochlea implant may partially restore hearing. Due to the very high cost of cochlear implant, research in this field is the need of the hour. The aim of this paper is to make the people of developing countries like India well aware about the working of cochlear implant, its vast advantages and fewer disadvantages. This study will encourage the Govt. to invest highly in the field of cochlear implants and provide necessary subsidy to the needy people This will eventually help the people suffering from profound deafness and enable them to hear like normal human beings bringing back the lost colours in their lives and eventually help them to lead a better tomorrow.

Key words: Cochlear Implant, Major Breakthroughs in Cochlear Implant

I. Introduction

A cochlear implant (CI) is a prosthetic device surgically implanted into the inner ear that is used to restore partial hearing in profoundly deaf people. This device is applicable only to those patients whose auditory nerves are intact. The function of CI is a replacement of damaged inner ear using external Body Worn Speech Processor (BWSP) and internal receiver stimulator. The stimulator stimulates auditory nerve via electrode array that enable understanding the speech by brain. CI has undergone several advancements in terms of signal processing strategies, the transmission link and the electrode array. Signal processing strategies plays a significant role in performance of CI. The speech processing strategies need more precise imitation of biological cochlear function so that more subtle control of auditory nerve response is possible. There exist different schemes of transmitting the signal from external processor to the implanted electrodes.

CIs can restore partial hearing to profoundly deaf people; the main function of these prostheses is to electrically stimulate the auditory nerve using an electrode array inserted in the cochlea. The acoustic signal is picked up by a microphone and analyzed. Then the extracted parameters of the signal are coded to generate electrical signals reconstituting the original signal. Currently all commercialized implants are multichannel they allow to stimulate the auditory nerve at different place of the cochlea, exploiting the ton topic coding of the frequencies. The success of CI can be attributed to the combined efforts of scientists from various disciplines including bio-engineering, speech science and signal processing.

II. Advantages and Disadvantages of Cochlear Implants

Cochlear implants can help people who:

- have moderate to profound hearing loss in both ears.
- receive little or no benefit from hearing aids.
- score 50% or less on sentence recognition tests done by hearing professional in the ear to be implanted.
- score 60% or less on sentence recognition tests done by hearing professionals in the non-implanted ear or in both ears with hearing aids.

Cochlear implants are highly successful for restoring hearing capabilities in people suffering severe-profound hearing loss. Cochlear implants are a better alternative to hearing aid devices which are only used to restore partial deafness. Cochlear implant is highly beneficial as many adults with cochlear implant report that they:

A. Hear better with a cochlear implant than with a hearing aid

A previous study has shown that people with cochlear implant achieve an average of 80% sentence understanding, compared with 10% sentence understanding for hearing aids.

B. Can focus better when in noisy environments

This allows them to have conversations with people across meeting tables, in restaurants and other crowded places.

C. Reconnect with missed sounds that they could not hear before their cochlear implant

D. Feel safer in the world as they can hear alarms, people calling out and approaching vehicles.

E. Talk and hear on the phone

Cochlear implants though being highly successful suffers few disadvantages
Cochlear implant requires a surgical process to get the device implanted which in turn depends upon the competency of the surgeon. Another drawback is the cost of the device and the surgical process to get the device implanted. This is one of the major hurdles in its evolution. Once a manufacturer's device is implanted, the implantee has no option but to remain with that device for life, unless the device fails or the implantee elects to pay for another surgery/device which is highly unlikely given the cost.

However despite of these drawbacks Cochlear implants find high success rate particularly in developed countries and its success overshadows its few limitations.

III. Cochlear Implant Model

Cochlear implants as we know them now are the result of intensive research over the last four decades. However, there is a long history of attempts to provide hearing by the electrical stimulation of the auditory system. The centuries old interest in the biology application of electricity was the basis for the development of cochlear implants.

A. Research during the late 18th and 19th centuries

Interest in the electrical methods of stimulating hearing had its beginnings in the late 18th century when Alessandro Volta discovered the electrolytic cell. Volta was the first to stimulate the auditory system electrically, by connecting a battery of 30 or 40 'couples' (approximately 50V) to two metal rods that were inserted into his ears. When the circuits were completed, he received the sensation of 'une recousse dans la tate' ("a boom within the head"), followed by a sound similar to that of boiling of thick soup. Volta's observation sparked sporadic attempts to investigate the phenomenon over the next 50 years, but the sensation the patients described was always momentary and lacked tonal quality.

Crude applications of electrical stimulation were described through the 18th and 19th century in Paris, Amsterdam, London, and Berlin. (Clark and Niparko). Since sound is an alternating, disturbance in an elastic medium, it was soon realized that stimulating the auditory system with a direct current could not reproduce a satisfactory hearing sensation. The next step was taken by Duchenne of Boulogne who, in 1855, stimulated the ear with an alternating current that he produced by inserting a vibrator into a circuit containing a condenser and induction coil. What resulted was a sound that resembled, 'the beating of a fly's wings between a pane of glass and a curtain'. (Clark) This was better, but still not satisfactory.

B. Interest Renewed: Breaking ground during the early 1900's

The initial optimism surrounding the bioelectrical approaches to cure deafness was followed by a period of skepticism as the applications appeared to be invasive and required ongoing critical evaluation. However, in the 1930's, interest was renewed in the problem of reproducing hearing artificially. This coincided with the introduction of the thermionic valve, which allowed for the auditory system to be stimulated electrically with significantly greater precision.

The work of Wever and Bray (1930) demonstrated that the electrical response recorded form the vicinity of the auditory nerve of a cat was similar in frequency and amplitude to the sounds to which the ear had been exposed. Meanwhile, the Russian investigators Gersuni and Volokhov in 1936 examined the effects of an alternating electrical stimulus on hearing. They found that hearing could persist following the surgical removal of the tympanic membrane and ossicles, and thus hypothesized that the cochlea was the site of stimulation.

- Another set of researchers, Stevens and Jones (1939), thought that electrical could be transduced into sound vibrations before it reached the inner year. Hearing induced in this way has been called the electrophonic effect. They were able to determine whether a linear or non-linear transducer was involved by the presence and strength of the overtones, which were detected when the subject heard beats. The studies by Stevens and Jones (1939), as well as Jones et al (1940) indicated that when the cochlea was stimulated electrically, there were three mechanisms, which produced hearing:
- The middle ear could act as a transducer, which obeys the 'square law' and convert alternations in the strength of an electrical field into the mechanical vibrations that produce sound.
- Electrical energy could be converted into sound by a direct effect on the basilar membrane, which would then vibrate maximally at a point determined by the frequency and these vibrations would stimulate the hair cells.
- Direct stimulation of the auditory nerve produced a crude hearing sensation.

Their conclusions were basically correct, although now other body tissues have been shown to act as transducers (Clark).

C. Major Breakthroughs

In 1950, Lundberg performed one of the first recorded attempts to stimulate the auditory nerve with a sinusoidal current during a neurosurgical operation. His patient could only hear noise. However, a more detail study followed in 1957 by Djourno and Eyries, provided the first detailed description of the effects of directly stimulating the auditory nerve in deafness. In their study, the stimulus appears to have been well controlled. Djourno and Eyries placed a wire on the auditory nerves that were exposed during an operation for cholesteatoma. When the current was applied to the wire, the patient described generally high-frequency sounds that resembled a "roulette wheel of the casino" and a "cricket". The signal generator provided up to 1,000-Hz and the patient gradually developed limited recognition of common words and improved speech-reading capabilities. The patient was found able to discern differences in pitch at increments of 100 pulses and was found able to distinguish words such as "pap', mamn"and "allo".

In 1964, Doyle et al., reported inserting an array of electrodes into the cochlea of a patient with total perceptive deafness. The electrodes were designed to limit the spread of the electrical field and were stimulated in sequence with threshold square waves that were superimposed with speech signals. The four electrodes were not especially implanted to take advantage of the spatial distribution of the auditory nerve fibers responding to different frequencies, and the result obtained was only satisfactory. However, it was significant that the patient was able to repeat phrases.

Yet another researcher, Simmons (1966) provided a more extensive study in which electrodes were placed through the promontory and vestibule directly into the modiolar segment of the auditory nerves. The nerve fibers representing different frequencies could be stimulated. The patient was tested to assess the effect of alterations in the frequency and intensity of the signal. The subject demonstrated that in addition to being able to discern the length of signal duration, some degree of tonality could be achieved.

The clinical applications of electrical stimulation of the auditory nerve were refined by House (1976) and Michelson (1971) through scala tympani implantation of electrodes driven by implantable receiver-stimulators. Dr. William House observed the percepts of patients when small electric currents were introduced to the promontory during middle ear procedures under local anesthesia. But technical barriers proved frustrating. During the early sixties, House implanted several devices in totally deaf volunteer patients. Although these were rejected due to lack of biocompatibility of the insulating material, that they worked for a short time provided optimism towards a solution for sensorineural deafness. (House testimonial). House teamed up with Jack Urban, a very innovative engineer, to ultimately make cochlear implants a clinical reality. The new devices benefited from the increasing capabilities for microcircuit fabrication derived from space exploration and computer development.

Through the 1990's, clinical and basic science studies have resulted in progress in implant technology and in clinical approaches to cochlear implants. Electrode and speech processor now produce coding strategies that are associated with successively higher performance levels. The commercial success of the Nucleus device has triggered the acceptance of implants as assistive devices. Over the years, implant patients have become more numerous and risks have been minimized. More people have accepted that implants are here to stay, and are increasingly being recommended. Currently, there are two major corporations manufacturing cochlear implants for use in the United States. Cochlear Corporation and Advanced Bionics Corporation.

IV. Conclusion

A cochlear implant (CI) is a prosthetic device surgically implanted into the inner ear that is used to restore partial hearing in profoundly deaf people. As the cost of cochlear implant being very high, research in this field is the need of the hour. The Govt.should take necessary steps to invest highly in the field of cochlear implants and provide necessary subsidy to the needy people This will eventually help the people suffering from profound deafness and enable them to hear like normal human beings bringing back the lost colours in their lives and eventually help them to lead a better tomorrow.

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