Matt Kastan
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BME Seminar 1

The ear consists of three main parts; the outer ear, middle ear, and inner ear. A sound or acoustic pressure wave received by the outer ear proceeds to travel along the auditory canal. The middle ear is responsible for converting the pressure wave to a mechanical vibration via small bones known as the ossicles. These vibrations are translated into a fluid medium located in the inner ear or the cochlea. The basilar membrane enclosing the fluid proceeds to move as a result of the vibration in the fluid. The displacement of this membrane is a direct result of the frequency associated with the external stimuli. Low frequency sounds result in maximum amplitude of displacement of the membrane at the apex while high frequency sounds produce maximum displacement of amplitude near the base of the membrane. Frequencies in between will result in maximum displacement at different points along the basilar membrane. The cochlea's function resembles a spectrum analyzer with its ability to distinguish frequencies. Attached to the membrane are hair cells which bend according to the displacement of the membrane. The bending results in the release of an electrochemical substance which causes auditory neurons to fire. Excitation at a particular part of the inner ear relates information about the acoustic signal to the brain. The brain can decipher what was heard provided knowing what part of the inner ear was stimulated. The basilar membrane and the hair cells are solely responsible for translating mechanical information to neural information. When large numbers of these hair cells become damaged, severe hearing loss results.

The notion of hearing restoration would have been though a miracle forty years ago. It was not until then that scientists began to experiment with electrical stimulation of the auditory nerve. Most often when a person loses their hearing, it is not the auditory nerve that is damaged but the stimulus (hair cell) responsible for producing the neural electrical impulse. The theory behind the cochlear implant is to bypass the outer, middle and part of the inner ear and directly excite auditory neurons through electrical stimulation. Components familiar to all cochlear implants include: a microphone to receive sound, a signal processor that converts the sound to electrical signals, a transmission system that transmits the electrical signals to the implanted electrodes, and an electrode or an electrode array surgically implanted into the cochlea.

Single-channel implants allow for the use of only one electrode while multiple channel implants consist of an array of electrodes inserted into the cochlea. This is done so that different auditory nerve fibers can be stimulated at different places in the cochlea. Different electrodes are stimulated depending upon the frequency of the signal. The signal processor acts to simulate normal cochlea function in that it breaks the input signal to component frequencies and delivers these signals to the appropriate electrodes. The receiving of a signal by an electrode forces an electrical impulse that stimulates a nerve fiber to fire and propagate neural impulses to the brain. The strength of the sound loud or soft is a function of the amount of nerve fibers activated. Loud noises result in large numbers of nerve fibers to

be activated while soft sounds associate with small amounts of nerve fibers activated. Nerve fiber activation is a function of stimulus current. Another characteristic of sound, pitch is a function of place, or where the cochlea is stimulated. Stimulate the apex to elicit low pitch sensations while high pitch sensations are elicited when electrodes near the base are stimulated.

Several important characteristics are able to distinguish cochlear implants. One of the main characteristics includes the electrode design, specifically number of electrodes and the electrode configuration. Electrodes may be placed extracochlear or intracochlear in the scala tympani. This method is preferred because it adheres to the previously mentioned normal cochlea for coding frequencies. The depth of the implantation within the cochlea is between 20 and 30 mm.

Another distinguishable characteristic between implants is the type of stimulation. Analog stimulation is when the filtered acoustic waveform is presented to all of the electrodes simultaneously. The theory behind this is that the nervous system will sort the information contained in the raw waveform. A disadvantage to this type of stimulation is that the simultaneous nature might cause channel interaction. Pulsatile stimulation is where the information is sent to the electrodes via pulses. The amplitude of the pulse is taken from envelopes of filtered waveforms. In this type of stimulation, pulses are sent in a non overlapping fashion. As a result, channel interaction is minimal.

The link between the implanted electrodes and the external processor differ from implant to implant. The two main types of transmitting signals occur either through a transcutaneous or percutaneous connection. Transcutaneous connections allow fro the stimuli to be transferred to the electrode through a radio frequency link. An external transmitter encodes the signal while an internal receiver decodes the signal and delivers the stimuli to the according electrodes. Percutaneous devices transmit stimuli to electrodes via direct plug connections. These devices require no other implanted electronics other than the electrodes.

The most significant characteristic of the device is in fact the signal processor. Various strategies exist for transforming speech signal to electrical stimuli. Some techniques are geared toward transmitting waveform information while others are concerned with the transmission of envelope information.

References:

1) www.utdallas.edu/~loizou/cimplants/tutorial/tutorial.htm

2) www.entnel.org/healthinfor/ears/cochlear -implant.cfm

3) www.nicoletbiomedical.com/home.shtml