Cochlear implants

By Susan Bennington, R.N.

The cochlear implant is an exciting new development that will ultimately help many profoundly deaf people. For a bilaterally deaf person with an intact auditory nerve who is unable to benefit from a conventional hearing aid, this information is very exciting.

What is a cochlear implant?

The cochlear implant is a device inserted percutaneously or transcutaneously that electronically stimulates the cochlear nerve fibers so that a sensation of sound is produced. Twenty years of research have gone into the development of this implant with the vast majority of the research being done in the last three years. Research has determined that many cases of total deafness are found at the hair cell level in the cochlea, with the patient having some degree of auditory nerve function. Only a few fibers of the cochlea nerve are necessary for stimulation to give a sensation of sound. This implant, therefore, is an electronic device that transforms sounds into electrical signals to stimulate cochlea nerve fibers in the absence of the functioning hair cells.

Anatomy and physiology

To properly understand how the cochlear implant works, a review of the anatomy of the ear along with the physiology of hearing is helpful. The ear is divided into three divisions, the external, the middle and the inner ear.

The external ear consists of the auricle or pinna. Its function is to collect the sound waves and channel them down the auditory canal to the eardrum or tympanic membrane. The tympanic membrane stretches across the deepest part of the ear canal and separates the external auditory canal from the tympanic cavity or middle ear. This membrane vibrates when the sound wave reaches it.

The middle ear is an air-filled cavity with three small ossicles that form a chain separating the middle ear from the inner ear. These ossicles (the malleus, incus and stapes) amplify the vibration of the tympanic membrane and pass it on to the cochlea. The base of the stapes fits into the oval window, a small opening between the middle and inner ear. Below the oval window is the round window, which also separates the middle and inner ears. The round window is covered with a mucus membrane called the secondary tympanic membrane.

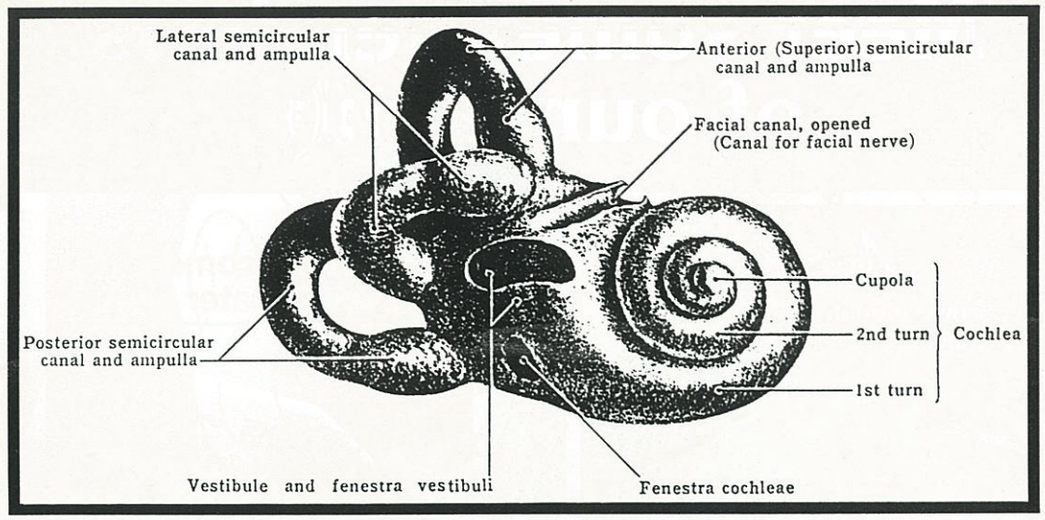
The cochlea

The inner ear consists of a bony labyrinth and a membraneous labyrinth. The bony labyrinth can further be divided into the vestibule, cochlea and semi circular canals. The semi circular canals are essential to the sense of balance.

The cochlea is a spiral tube that contains the nerves that transmit sound to the brain. The inner ear lies within a portion of the temporal lobe and contains two separate fluids. One of the fluids, the perilymph, acts as a cushion to the receptors of hearing and is continuous with the sub arachnoid space and cerebral spinal fluid through the cochlear duct. Inside the cochlea is the organ of Corti which is the organ of hearing. It extends along the length of the cochlea and has sensitive hair cells or cilia that are set in motion by the vibrations of the ossicles. The motion of these hair cells become electrochemical impulses that are passed along the 8th cranial nerve (vestibulocochlear nerve) to the brain where they are interpreted as sound.

About the author

Susan Bennington, R.N., took her diploma nursing course at Okanagan College in Kelowna, B.C. She has worked at the Toronto General Hospital and St. Paul's Hospital in Vancouver, where she studied the Operating Room Technique and Management Course.



Lateral view of bony labyrinth and cochlea

How the implant works

Many devices have been developed to stimulate the auditory nerve. These can be separated into single and multi channel implants. An implant can either be percutaneous, meaning it projects through the skin or transcutaneous, where it is implanted directly under the skin.

Approximately half dozen companies around the world manufacture cochlear implants. Each design has different advantages and disadvantages. At this time it is difficult to properly compare the advantages and disadvantages of each device because no standard of testing has yet been established. Long term follow-up is not available yet and there have been very few comprehensive reports from independent research centers. The doctor implanting the device will choose a particular model based on his or her testing of the patient and the model he/she feels will best suit the patient's needs.

The cochlear nerve fibers are stimulated by electrical signals received by the implant from a speech processor. All implants have a speech computer processor worn outside the body that picks up sound. The microphone then changes the acoustic information into an electrical signal or energy. The processor amplifies this electrical energy, filters it and passes it to the transmitter. In the percutaneous model the transmitter is connected by a direct wire to the receiver implanted behind the ear.

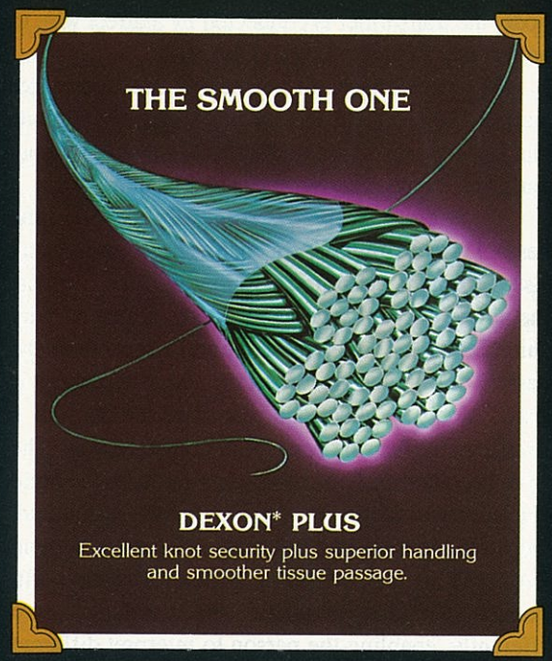
With the transcutaneous model the transmitter changes the electrical energy into magnetic currents which are passed through the skin's surface, without being felt, to the receiver implanted behind the ear.

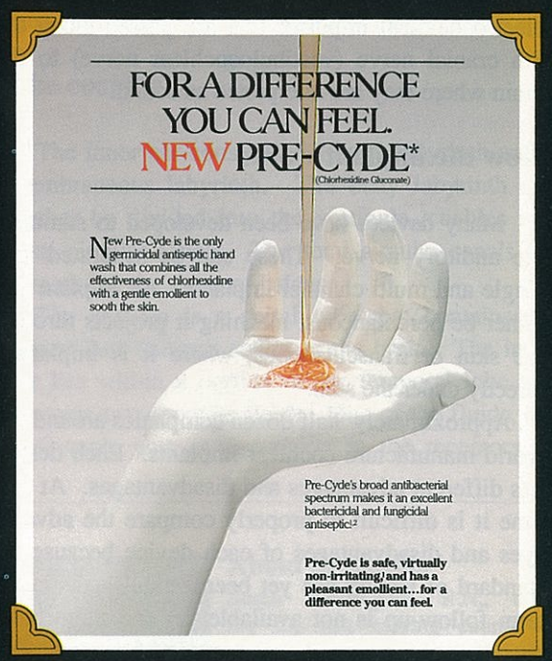
The internal receiver is surgically placed in the mastoid bone with the intra cochlear electrode being passed through the round window into the cochlea. The single channel models also have a ground wire which is placed under the temporalis muscle in the mastoid or middle ear. When the electrical energy is passed along the electrode placed in the cochlea it stimulates the hearing nerve (8th cranial nerve). The nerve becomes excited and sends a signal to the brain which interprets this as a sound for the individual. The multi channel implant does not have a ground wire. The several individual points along the multi channel electrode stimulate the auditory nerve differently, enabling the person to interpret different frequencies of sound at different volumes.

Implant eligibility

The cochlear implant is not a cure for deafness. It

Meet some members of our family





quality professional products from

DG DAVIS+GECK A TRADITION OF INNOVATION

Cyanamid Canada Inc. Atria North, 2255 Sheppard Avenue East, Willowdale, (Ontario) M2J 4Y5

*Registered Trademark of Cyanamid Canada Inc.

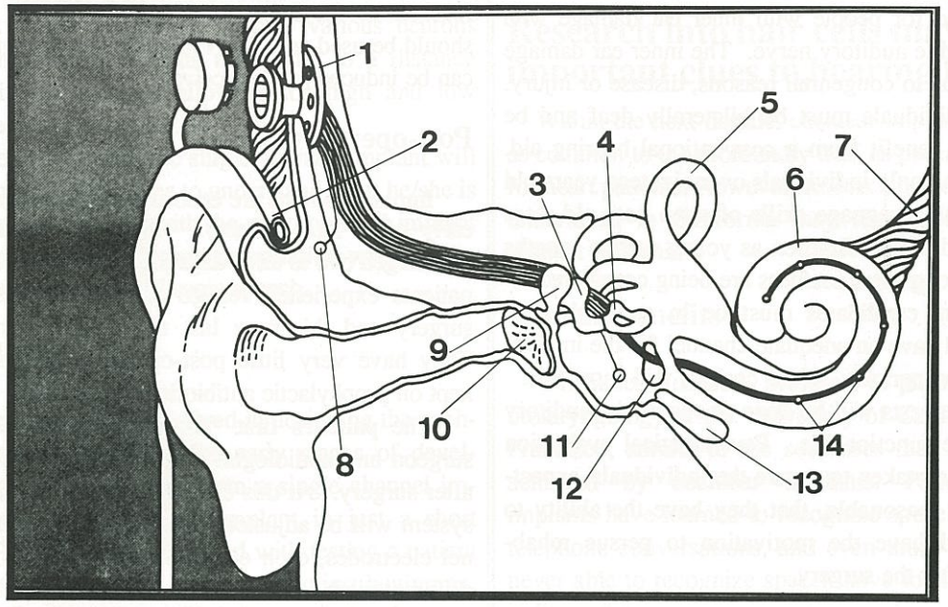


Illustration of a percutaneous cochlear implant

(1) Percutaneous pedestal
(2) Microphone
(3) Incus
(4) Stapes
(5) Semicircular canal
(6) Cochlea
(7) Auditory nerve
(8) Indifferent or non-contact electrode
(9) Malleus
(10) Tympanic membrane
(11) Indifferent electrode
(12) Window through promontory bone visually accessing first turn of cochlea
(13) Eustachian tube
(14) Contact electrodes

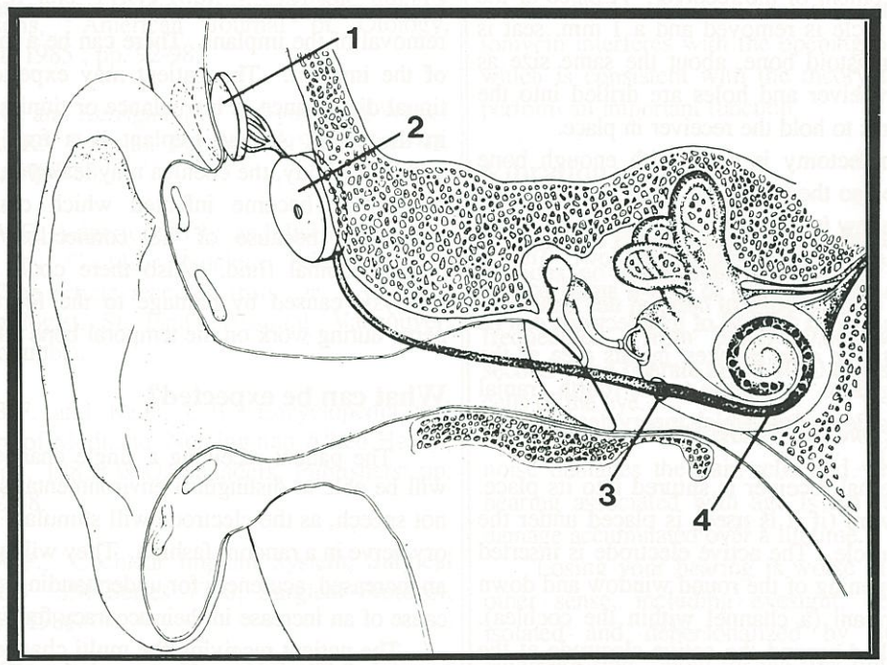


Illustration of a transcutaneous cochlear implant

(1) Internal antenna (2) Receiver (3) Window through promontory bone (4) Electrode

is designed for people with inner ear damage who have a viable auditory nerve. The inner ear damage may be due to congenital reasons, disease or injury. These individuals must be bilaterally deaf and be unable to benefit from a conventional hearing aid. At one time only individuals over eighteen years old and with the language skills of a ten year old were considered. Now children as young as five months old with congenital deafness are being considered.

Implant candidates must be in good physical health and have an adequate channel for the implant device. Tomography of the cochlea will show this.

Further tests will be done to ensure the auditory nerves are functionable. Psychological evaluation will be undertaken to ensure the individuals' expectations are reasonable, that they have the ability to adjust and have the motivation to persue rehabilitation after the surgery.

Surgical intervention and procedure

Positioning, prepping and draping of the patient is to be done according to the hospital procedure for a mastoidectomy.

Placement of the receiver, either internal or external, is behind the pinna without touching the pinna but allowing for glasses to be worn. A post auricular incision is made about 1 cm. outside the expected placement of the receiver. A piece of the temporalis muscle is removed and a 1 mm. seat is cut into the mastoid bone, about the same size as the internal receiver and holes are drilled into the bone for sutures to hold the receiver in place.

A mastoidectomy is done with enough bone being removed so the top of the incus is visible and the round window is exposed. The incus is removed for better visability of the round window. Then a small diamond burr is used to drill a small hole in the round window so the ball of the electrode can be inserted. Extreme care is taken in this area as the work is being done very close to the fourth cranial nerve (the trochlear nerve which innervates the nerve to the eyeball).

The internal receiver is sutured into its place. The ground wire (if it is used) is placed under the temporalis muscle. The active electrode is inserted through the opening of the round window and down the scala tympani (a channel within the cochlea). Fascia is packed around the active electrode at the round window and the wound is closed in layers.

If cautery is used after the placement of the receiver or for future surgery only bipolar cautery should be used as it will minimize the current which can be induced in the receiver.

Post-opertative care

Implant patients are encouraged to ambulate very early after their surgery. They are often being discharged two to three days post-operatively. Many patients experience vertigo (dizzyness) after their surgery and this may last up to several months. They have very little post-operative pain and are kept on prophylactic antibiotics for ten days.

The patient's first "training session" with the surgeon and audiologist will be about 3 - 5 weeks after surgery. At this time the external parts of the system will be adjusted. On the newer multi channel electrodes, each electrode piece will produce a different pitch sensation. These are fine tuned individually for a particular pitch and loudness, according to the hearing response of the individual. This will allow the patient to hear a variety of pitches both low and high and can be readjusted over time if any changes occur in the patient's hearing.

Complications

Prior to having the surgery the patient should be aware of the complications that can happen post-operatively, which may necessitate the removal of the implant. There can be a total failure of the implant. The patient may experience continual disturbance in his balance or tinnitus (ringing in the ear). As the implant is a foreign object within the body, the cochlea may leak purulent fluid or it may become infected which could cause meningitis because of it's connection with the cerebral spinal fluid. Also there could be facial paralysis caused by damage to the fourth cranial nerve during work on the temporal bone and muscle.

What can be expected?

The patient receiving a single channel implant will be able to distinguish environmental sounds but not speech, as the electrode will stimulate the auditory nerve in a random fashion. They will experience an increased acuteness for understanding speech because of an increase in their accuracy for lip reading.

The patient receiving the multi channel implant will be able to differentiate between frequency and volume and this will allow him to understand some speech. This is possible because various neurons are stimulated at various times due to a distance delay in the electron allowing for high and low frequency to be transmitted.

The patient with the single channel implant will still require visual clues to understand what he/she is hearing. The patient with the multi channel implant appears to receive enough information without visual clues to understand some speech.

Conclusion

The technology involved in designing the cochlear implant is still in the early stages of development. We have gone from a single channel implant to a multi channel implant in just a short time. The principles involved with testing a patient and with the operative procedure are just beginning. Our ability improves with every new development and there are greater improvements yet to come. For the person who is living in a world of silence, and cannot be helped with a standard hearing aid, just the thought of possibly being helped and maybe "hearing" again must be nothing short of a miracle. ■

Bibliography

Gantz, B.J. and Tyler, R.S., "Cochlear Implant Comparisons," American Journal of Otology, November, 1985 ; pp. 92-98.

Iadarola, G. and Kerrigan, M., "Do you Hear What I Hear," AORN Journal, February, 1986, Vol. 43, No. 2, pp. 478-483.

House, W.F.; Edgerton, B.J.; and Itselberger, W., "Hearing by Cochlear Nucleus Stimulation in Humans," an article received from Dr. J. Cleland, Otolaryngologist, St. Paul's Hospital, Vancouver, British Columbia.

Miller, B.F. and Kean, C.B., Encyclopedia and Dictionary of Medicine, Nursing and Allied Health, 3rd Edition, 1983; W.O. Saunders, Publishers; pp. 351, 247-248.

House. W.F., "Cochlear Implant System, Surgical Procedure," 3M Series 7700, Surgical Protocol, November, 1984.

Tartora, G. and Anagnostakos, N.P., "Principles of Anatomy and Physiology," 3rd Edition; Harper and Row Publishers, 1981; pp. 399-403.

Research into hair cells may hold important clues to hearing loss

Within the next decade, cochlear implants may be as common to the profoundly deaf as pacemakers are for heart patients. However, research presently being undertaken in California may leave the cochlear implant far behind.

Implant benefits

Dr. James Hudspeth, professor of physiology and otolaryngology at the University of California, San Francisco, admits to the successes that have been achieved by cochlear implants. Patients with implants have learned to recognize speech, conduct telephone conversations, and even those who were never able to recognize speech have found it useful in lip reading.

Through his study of the hair cells in the inner ear, he hopes to prevent hearing loss or cure it without the need for an implant.

Ten years ago, Dr. Hudspeth made a major technical leap by developing ways to study hair cells in a test tube. Since then, he has discovered small pores in the tips of the hairs that appear to open when the hairs slide past one another as they vibrate or rock to and fro.

In 1985 he showed that the antibiotic streptomycin interferes with the opening of these pores, which is consistent with the theory that the pores perform an important function.

Vibration range

The hairs respond to sounds so faint they produce motions no larger than the size of the hydrogen atom and can respond to a great range of vibrational frequencies - from 20 to 20,000 vibrations per second - and operate about 1000 times as fast as the cells of the eye.

Dr. Hudspeth is interested in how factors such as noise damages the hair cells and whether loss of hearing associated with age is the result of noise damage accumulated over a lifetime.

"Losing your hearing is worse than losing any other sense, including eyesight. People become isolated and depersonalized by deafness," Dr. Hudspeth said. "Now for the first time, there is the hope of being able to restore their hearing. The psychological benefits alone will be enormous."