**Key Terms**

**Cochlear implant**: an electric device that is used to treat hearing loss in the inner ear

**Sensorineural hearing loss (SNHL)**: hearing loss that results from issues in the inner ear with conducting electric signals

**Cochlea**: organ in the inner ear that contains hair cells

**Sound pressure waves**: waves that result from the vibrating of particles in the medium the sound is traveling through.

**Hair cells**: hairlike, sensory parts of the cochlea that turn sound waves into electrical signals when they vibrate

**Scala tympani**: the bony passage into the cochlea that helps conduct sound waves; an optimal place for cochlear implants

**Voltage**: force that pushes electricity into flow

**Frequency**: speed of a sound vibration

---

**ABSTRACT**

Cochlear implants are a common treatment for sensorineural hearing loss. The design of the implants have improved over time, but they are still bulky for patients because of the external parts, which cause functional and style related issues for users. Research has been done to design implants that can be placed completely inside the ear, but there are still flaws in these models. One solution is to make a device that can record the pressures inside the cochlea in response to various sounds. This pressure is what causes the hair cells in the cochlea to move and transform the sounds into electrical messages for the brain. Recording it will allow an artificial device, like a cochlear implant, to do the same!

Here, researchers investigated whether the sound pressure within the cochlea could be measured and used as input to the processor of a cochlear implant. They inserted the sensor into the scala tympani, a known optimal spot for cochlear implants, and measured how it responded to a sound played outside the ear. They found that the sensor could act like a microphone for the implant, bringing scientists closer to making a fully implantable microphone.
WHAT IS SOUND? HOW DO WE HEAR IT?

Sound is made when something vibrates and sends pressure waves, called vibrations to our ears. Vibrations are like moving a stretched cord quickly back and forth. They travel through air to the ear, causing the eardrum and inner ear to vibrate too (Figure 2). A louder sound means a stronger vibration. That’s why as you get farther from a sound source, it feels fainter to you!

WHAT IS SENSORINEURAL HEARING LOSS?

Sensorineural hearing loss happens in the inner ear when the tiny hair cells get damaged and can’t convert the sound pressure into electrical signals for the brain to interpret. It’s commonly caused by things like frequent exposure to very loud noises, genetics, and natural aging. As a result, many older people naturally have this kind of hearing loss and it can range from mild to complete deafness. A common treatment for sensorineural hearing loss is a cochlear implant.

HOW DO COCHLEAR IMPLANTS WORK?

Cochlear implants are machines that help fix hearing problems within the inner ear. The implants skip over the damaged parts of the ear to send sound signals to the hearing nerve. Sounds are captured and sent to a receiver that is located behind the ear. This receiver transfers the signals to parts inside the cochlea to allow electricity to pass through. The signal stimulates the hearing nerve and travels to the brain, like a normal sound signal. But, because of the extra steps in capturing the sound with the receiver, there is a slight delay in hearing!
Researchers used bones and tissues from human bodies to create an artificial ear structure. They were frozen and later shaped to allow access to the opening from the middle to the inner ear. Their sensor was prepared with a special type of plastic. Up to 12 mm of the sensor was inserted into the ear’s scala tympani through the opening from the middle ear.

For every 2 mm of the sensor they inserted, they measured the voltage output of the sensor along with the pressure in the ear canal. While the sensor was inserted, they played 10 sounds of different frequencies and volumes at the ear canal with a speaker. To get a baseline, they measured the output of the sensor while it was held in the air of the middle ear space or resting on the opening to the inner ear.

**METHODS**

For low frequency sounds, the voltage output was as intense (or high amplitude) as the original sound waves. But, for high frequency sounds, the intensity dampened, and the amplitude was much smaller.

**RESULTS**

- For low frequencies, the pressure in the sensor matched the pressure in the ear canal. At higher frequencies, the pressures in the sensor matched that of the sensor in the air, meaning the voltage output it produced was less strong (Figure 3).

**Figure 3.**

**Figure 4.** When the sensor was inserted at deeper depths (orange), low frequency sounds were detected louder and more clearly, shown by the smoother curve. At shallower depths (blue), the signal was overall fuzzier and less stable for all frequencies, shown by the jagged and unpredictable graph.
CONCLUSIONS

- They demonstrated how their sensor could accurately detect the internal cochlear pressure after sound exposure to the ear canal but mostly for lower frequency sounds.
- Full insertion of the sensor resulted in voltage signals above the control level for low frequencies, but not to the full range of human hearing.
- Inserting the sensor does not affect middle ear function, which is important for a successful sensor.
- Smaller depth insertions resulted in lower sensitivity, meaning the sensor was not able to detect as much sound or filter out extra noise.

WHAT'S NEXT?

Does this mean we can turn people with hearing loss into cyborgs like in Figure 5? Not quite, but with some improvements, we may be able to improve the device’s sensitivity, allowing it to cover full range of human hearing, including higher frequencies. New research in the neuroscience of sensation and perception is promising! The long term goal is to put the sensor inside a typical cochlear implant electrode to allow the device to measure intracochlear sound pressure. The result would be a fully implantable cochlear implant!

Would you like to live in a world of bionic humans? If you had sensorineural hearing loss, would you buy an implant like the one in this study?

Adapted by Deena Haque, Amy Ngo, and Sammy Tavassoli from An Intracochlear Pressure Sensor as a Microphone for a Fully Implantable Cochlear Implant by Elizabeth S. Olsen et al., Otology & Neurotology, 2016.