New imaging tool captures how sound moves through the chinchilla ear

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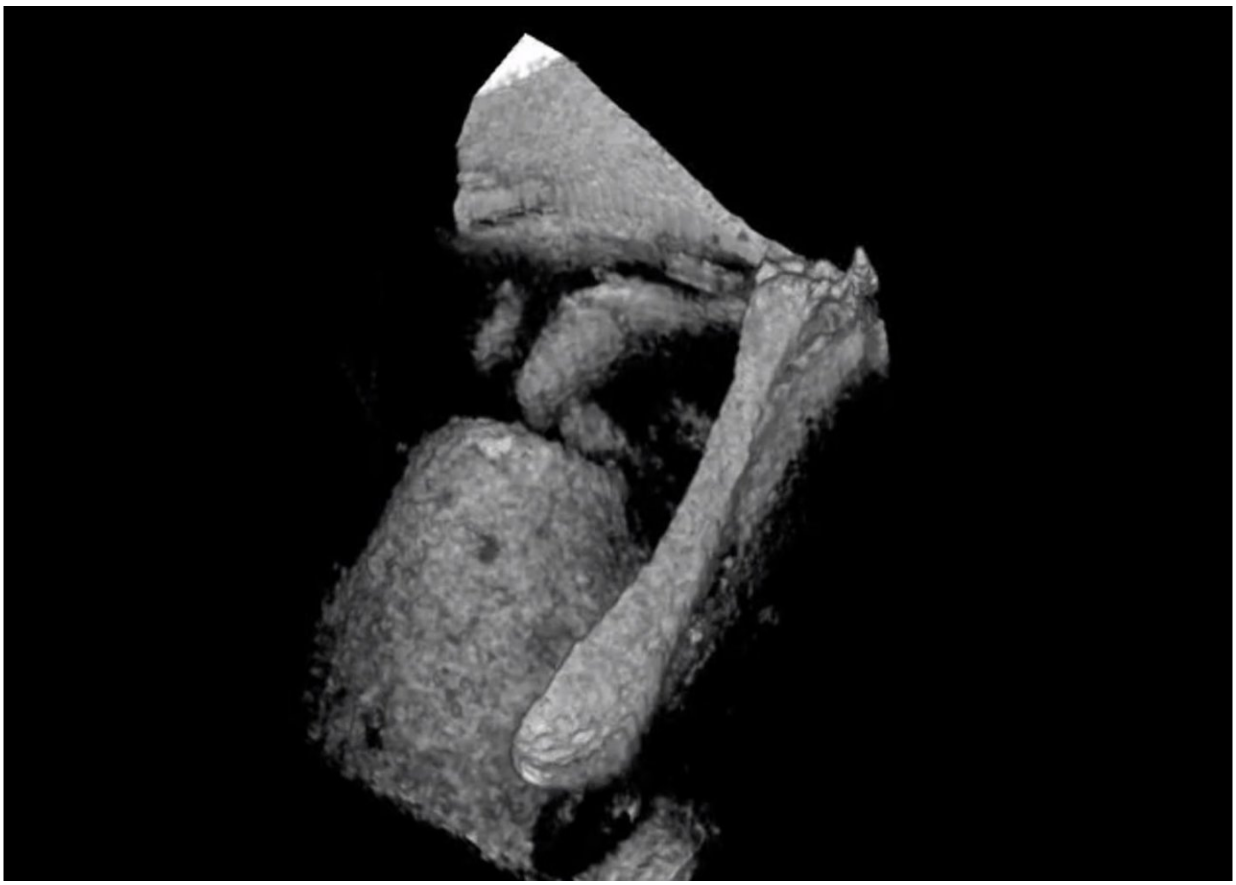

Using their newly developed OCT vibrography tool, researchers reconstructed the motion of ossicular bones in the chinchilla exposed to high frequency sound. The new technology allowed them to observe a previously unknown mode of ossicular motion at high frequencies. Credit: Optical Society of America

Researchers have developed a new device that can be used to visualize how sound-induced vibrations travel through the ear. The technology is providing new insight into how the ear receives and processes sound waves and, with additional development, might one day be used by physicians to diagnose diseases that affect hearing.

The new imaging tool is based on optical coherence tomography (OCT), a biomedical imaging technique, which can provide high resolution images of the microstructures of tissue. It can be used to image the middle ear through the intact eardrum and to measure the tiny vibrations within the ear that contribute to sound perception. The middle-ear ossicles, the smallest bones in the human body, form a chain that converts sound waves received by the eardrum into mechanical vibrations that can be detected by the inner ear.

In The Optical Society (OSA) journal *Biomedical Optics Express*, the researchers describe how they used the tool, which they call OCT vibrography, to make new discoveries about how ossicles in chinchilla cadavers respond to high-frequency sounds. The chinchilla is commonly used in hearing research because its ears are similar to those of humans in terms of size and sensitivity to different sound frequencies.

Watching the ear hear

"There are multiple theories of how high-frequency sounds are conducted to the inner ear, and the ability to view the sound-driven motion of large portions of the ossicular chain will help us understand what actually happens," said research team leader Seok-Hyun Yun of the Wellman Center for Photomedicine at Mass General Hospital.

With more development, the new technique could also find its way to the clinic. Although methods exist for identifying the presence of a problem with middle-ear sound conduction in people, diagnosing the exact problem and location requires surgically moving the eardrum to observe the middle ear.

"If our approach is accepted clinically, it would allow clinicians to differentiate between different middle-ear problems and plan a treatment strategy before, or instead, of performing surgery to view the area," said John Rosowski of Massachusetts Eye and Ear, co-leader of the project.

Measuring sound vibrations

To measure vibrations caused by sound in the middle ear, the researchers synchronized an OCT measurement system with sound from a high-fidelity speaker. As the sound from the speakers pushes on the eardrum, the bones begin to move and are imaged with OCT. The researchers developed algorithms to extract accurate measurements of the vibration from the OCT images.

Previous studies of the sound vibrations traveling through the middle-ear typically measured the motion of individual locations on the bones or from a collection of no more than 30 individual locations. The unique combination of high-resolution imaging and high-sensitivity vibration measurements available with OCT allowed the researchers to simultaneously measure structure and motion at over 10,000 points on the ossicular surface and eardrum.

The researchers demonstrated the capabilities of the new OCT vibrography system by measuring sound-driven eardrum and ossicular motion in chinchilla cadavers. They observed a previously unknown mode of ossicular motion at high frequencies that is consistent with some of the theories describing how high-frequency sounds travel to the inner ear.

"Our demonstration of a unique mode of ossicular motion at high frequencies has already led to new ideas of how the bones conduct sound to the inner ear," said first author of the paper Antoine Ramier of the Wellman Center. "That information may help define new ways for surgeons to reconstruct diseased ears."

Toward diagnosing disease

One reason the researchers used cadavers was that it took almost 60 seconds to acquire the measurements, during which the breathing and heartbeat of a live animal would likely cause artifacts in the motion measurements. The research team's colleagues at Dalhousie University in Canada are exploring whether measurements of the motion taken from 3 to 5 points, combined with an anatomical OCT scan of the whole eardrum and middle ear, may provide enough information to diagnose ear disease in living organisms.

The researchers plan to use their instrument to study ears from human cadavers to find out if the new mode of ossicular motion they found in chinchillas also occurs in humans. Future research will also further examine how this new tool could be applied in specific clinical applications such as diagnosing a particular disease or hearing problem.

More information: Antoine Ramier et al. Mapping the phase and amplitude of ossicular chain motion using sound-synchronous optical coherence vibrography, *Biomedical Optics Express* (2018). DOI: 10.1364/BOE.9.005489

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