# New ultrasound techniques for peering inside bony structures

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Ultrasound—sound with frequencies higher than those audible to humans—is commonly used in diagnostic imaging of the body's soft tissues, including muscles, joints, tendons and internal organs. A technology called high-intensity focused ultrasound (HIFU) is also being explored for therapeutic uses including the removal of uterine fibroids and the destruction of tumors.

The method has limitations, however, in large part because bones in the body reject, refract, distort and absorb the waves. Although most medical applications of ultrasound are able to work around bony structures, two parts of the body are particularly challenging: the liver (because it is mostly confined within the rib cage) and the brain (housed within the skull).

A suite of noninvasive, adaptive focusing techniques—that allow ultrasonic beams to be focused through the rib cage and skull—will be described during Acoustics '17 Boston, the third joint meeting of the Acoustical Society of America and the European Acoustics Association being held June 25-29, in Boston, Massachusetts.

Jean-François Aubry, director of research at CNRS (the National Center for Scientific Research in France) and an invited associate professor at the University of Virginia will explain how the technology behind HIFU is similar to how an optical lens (like a magnifying glass) focuses light. Here, however, an acoustic lens is used to focus multiple beams of ultrasound waves on the area of interest—say, a liver tumor. The beams are generated by piezoelectric transducers, or "elements"—devices that convert an electric current to mechanical stress.

"Tumor ablation [destruction] can be achieved by increasing the tissue temperature in targeted regions, until thermal necrosis is obtained—typically by warming the tissues up to 60 degrees Celsius over a period of 10 seconds," Aubry said. A bone, however, has an absorption coefficient that is 10 times higher than that of soft tissues—that is, bone absorbs sound waves 10 times more effectively than soft tissues—and this could lead to overheating of the ribs and even severe burns on the overlying skin.

To prevent this, Aubry and colleagues have developed a noninvasive "time-reversal" technique, called the DORT method, which focuses ultrasound waves through the ribs by taking advantage of the imaging capabilities of a multi-element array.

First, a sound impulse is emitted from each element in the array, and the corresponding backscattered echoes from the ribs are recorded. By analyzing the backscatter from multiple elements, it is possible to calculate the shape of an ultrasound beam that will sonicate in between the ribs, completely avoiding the bone.

Ultrasonography in the brain is complicated because the bone of the skull, in addition to heating up when an ultrasound beam is applied, distorts that beam, preventing it from being properly focused on the targeted tissue. One solution is the use of multi-element arrays in conjunction with computed tomography (CT) and magnetic resonance imaging (MR). CT-based simulations allow for an estimation of the phase shifts induced by the skull and the arrays generate beams that correct for those aberrations. MR is used to guide and monitor the treatment. As Aubry will describe in his talk, arrays with 1024 elements are now being used for the treatment of essential tremor, Parkinsonian tremors and brain tumors.

Although adding more and more elements to these probes can improve the focusing of the signal, a greater number of elements also means greater cost. To get around this, Aubry and his colleagues have developed and patented a lens-based transcranial focusing device that uses only one piezoelectric transducer element, covered with a 3-D silicone acoustic lens of variable thickness. This lens-based element, he said, is equivalent to an 11,000-element transducer in terms of its phase-shaping capabilities. Although it is not yet in clinical use, the single-element system could be used for low-intensity applications such as neuromodulation (the modulation of neuronal activity) and to punch localized and reversible openings in the blood-brain barrier; with future modifications, Aubry said, the system could be used to induce tumor necrosis.

Provided by Acoustical Society of America

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