Researchers magnify the brain in motion with every heartbeat

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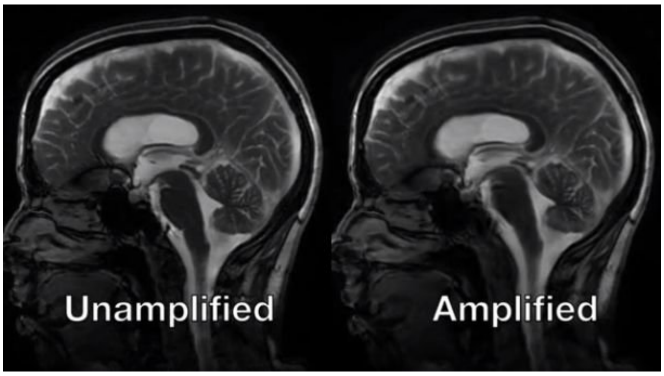

Understanding how the brain moves – at rest and upon impact – has been crucial to understanding brain disorders, but technology has lagged behind. Now, researchers at Stanford University and the University of Auckland have developed an imaging technique that reveals tiny brain motions providing a promising long-awaited diagnostic tool for obstructive disorders of the brain.

"Our new exciting method enables us to glance at the very subtle motion of brain tissue induced by blood pulsation and CSF flow" explains Itamar Terem, Stanford University research assistant and first author of the new study. "We are amplifying sub-voxel motion – motion that is smaller than the image resolution", he notes.

The brain moves slightly with each heartbeat, but these motions are tiny: on the order of ten to 180 micrometers, less than the width of a single human hair. Because these movements are so small, standard MRI techniques sometimes have difficulty capturing and displaying them well, limiting visualization of brain motion for monitoring or diagnosing obstructive brain disorders.

"We have succeeded in revealing small motions near the midbrain, spinal cord, cerebellum and even in areas such as the frontal lobe" says Itamar.

The new technique, reported in the May 29 online issue of Magnetic Resonance in Medicine, was originally developed by Samantha Holdsworth and Mahdi Salmani Rahimi at Stanford. There, Holdsworth and her team developed the foundations for a technique called amplified MRI (aMRI). In the past two years, Terem fine-tuned the technique, called phase-based aMRI, to show that it can be used for diagnostic benefit.

By coordinating the timing of the heartbeat with data acquired on the brain, one can stitch the data together to create images or "MRI videos" that move smoothly over the heartbeat. The team then tailored a phase-based video magnification algorithm developed by an MIT team, which detects and magnifies imperceptible changes in videos. By tailoring the video magnification algorithm to the MRI videos, the brain's motion can be amplified to a more visible scale.

"You can sometimes capture the whole head 'nodding' in the scanner due to the force of the blood pumping into the brain every time the heart beats," says Holdsworth, now at the University of Auckland and senior author of the recent study.

Holdsworth and Terem found phase-based aMRI produced fewer errors and gave better visibility than the original aMRI method, particularly areas of the brain that move most, such as the mid-brain and spinal cord. The phase-based aMRI code works by manipulating a series of mathematical operations used in image processing known as steerable-pyramid wavelet transformation, amplifying motion without the accompanying noise.

"Phase-based aMRI was less sensitive to noise and artifacts compared to the original aMRI method, showing superior image quality, with an overall reduction in shading over the cerebral cortex and spinal cord, and fewer [cerebrospinal fluid] flow artifacts," says Terem.

The team applied the technique on two subjects, a control and a patient with Chiari malformation I. The condition, present at birth, can cause many symptoms, including headaches or stiffness in the neck, due to malformations at the base of the skull and upper spinal area. Unlike the control participant, video images of the Chiari patient showed significantly larger brain movement in at least two locations.

"Better visualization and understanding of the biomechanical properties of the brain could lead to earlier detection and monitoring of brain disorders," notes Mehmet Kurt, collaborator on the project.

"aMRI may allow us to detect pathological brain and vessel motion due to diseases or disorders that obstruct the brain or block the flow of brain fluid," says Holdsworth.

The team will continue to advance the technology in clinical settings to larger numbers of patients with known medical diagnoses of various conditions such as hydrocephalous, cerebrovascular, and neurodegenerative disease.

More information: S.J. Holdsworth, W. Ni, G. Zaharchuk, M. Rahimi, M. Moseley. Amplified Magnetic Resonance Imaging (aMRI), Magnetic Resonance in Medicine (2016).

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