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CfA research advance creates tool for lung imaging

By Alvin Powell
Harvard News Office

In a basement laboratory at the Harvard-Smithsonian Center for Astrophysics (CfA), surrounded by instruments built to detect the universe's distant secrets, sits a machine that will help us look not outward to the stars, but inward at our own bodies.

Using know-how gained building instruments to peer into space and test the fundamental laws of physics, Ronald Walsworth, senior lecturer on physics at Harvard and senior physicist at the Smithsonian Institution, and his research team have created a walk-in, low-field MRI system that has Massachusetts General Hospital (MGH) imaging specialists searching for funding to move the machine from the CfA's hilltop complex in Cambridge to MGH's imaging research labs in Charlestown, Mass.

"The work is very exciting. I think it will have lots of applications," said Bruce Rosen, professor of radiology at Harvard Medical School and director of MGH's Martinos Center for Biomedical Imaging.

The new MRI uses inert, magnetized gas to boost the strength of the imaging signal inside the body. This allows the use of a much lower magnetic field outside the body to create the same detailed images that come from a traditional, high-magnetic-field MRI.

The machine's lower magnetic field allows the use of a smaller, walk-in magnet and flexibility on patient positioning that Rosen said can be important in studies of lung function.

"We spend most of the day upright and moving around, but MRI systems work with the patient lying down in the tube," Rosen said. "Blood flow as well as air flow are dependent on posture and are very different when lying down or sitting up."

MRI, or magnetic resonance imaging, is a medical imaging technology that has been in use since the 1970s. The technique uses powerful magnets to manipulate tiny amounts of magnetism that exists naturally within the body. This magnetism is contained in the nucleus of hydrogen atoms in the water that makes up a large part of all of us.

The body's natural magnetism is so tiny that traditional MRIs need enormous magnets to get an image. Patients typically lie on a bed that is fed into the MRI's doughnut-shaped magnet. The MRI's magnetic field is then manipulated and radio-wave signals applied to get an image.

MRI has become a critical tool for physicians seeking to understand what's going on inside the body. It creates detailed images of both hard and soft tissue and is used to detect everything from cancerous tumors to physical injuries, such as ligament damage in athletes.

The new low-field MRI grew out of research in Walsworth's lab in the 1990s that was originally intended for precision tests of Einstein's theory of relativity. It hinges on the ability of scientists to take an inert gas that won't interact with human tissues and make it highly magnetized through a process called hyperpolarization.

Much of Walsworth's research at the CfA focuses on things like testing relativity and the search for Earth-like planets around other stars. For example, his research team and collaborators recently devised a device, known as an "astro-comb," to greatly increase the resolution of planet detectors, which is being tried out now on a mountaintop in Arizona. Despite the apparent disconnect of such physical science experiments from medical imaging, Walsworth realized more than a decade ago that hyperpolarized gas had possible unique applications to lung imaging using a low-field MRI. To get the images, subjects breathe the hyperpolarized gas, usually helium or xenon, and sit, stand, or lie down in the MRI scanner while an image is being taken. The images are quickly acquired, taking only a few seconds, but can provide unique information not available with other MRIs, such as differences in distribution of oxygen in the lung of people when upright and lying down.

Walsworth said the current low-field MRI is the third generation of such instruments. In the late 1990s, his lab first built a small version that worked on animals and followed that up in 2003 with a prototype for use on humans, developed together with colleagues at the Brigham & Women's Hospital, Harvard School of Public Health, and the University of New Hampshire. The current low-field MRI incorporates changes based on lessons from the earlier machines.

"We cobbled together the first two systems mostly from parts already found in our labs," Walsworth said. "The current version is the first to be optimally designed and employ custom hardware."

In talking about the new technology, Walsworth reels off a list of people for whom it would be useful, including those with magnet-sensitive pacemakers, premature babies with problems of lung function, and obese patients for whom getting inside a traditional MRI might be difficult. He also spoke of future possibilities, where a hyper-polarized liquid or nanoparticles could be developed for injection, then letting the MRI image the circulatory system or find precancerous lesions.

Though there may eventually be other applications, the promise of a new kind of lung imaging has researchers taking notice.

Jose Venegas, associate professor of anaesthesia at Harvard Medical School and MGH, conducts research into asthma's effects on the lung and is interested in the low-field MRI's capabilities. Venegas said they often use PET, or positron emission tomography, to image lungs, but because it is radiation-based technology, there is a limit to how often the patient can be exposed.

"Being able to study a subject multiple times would be very useful in seeing how asthma develops, seeing the bronchial restrictions," Venegas said.

Venegas said the new low-field MRI could also be useful in watching how lung function changes as a patient shifts position, going from a sitting to lying position.

"I've taken a look at some of the data; it's very impressive," Venegas said. "I'm intrigued by the possibilities."

Rosen said he'd like to move the new machine from the CfA to MGH's Martinos Center. They have the lab space, he said, but they are still searching for funding to make changes to the space the new equipment will require. Once it moves in, Rosen said, they will begin to explore the possibilities of the new technology.

"One of the areas of research will be to really understand the role it may play," Rosen said. "I think it will have lots of applications."

Rosen called the work "a combination of clever physics and physiology," and said it isn't the first time an imaging collaboration occurred between Harvard medical imagers and astrophysics. The Astronomical Medicine project at the IIC uses the expertise of medical imaging on sky surveys and other astronomical projects.

Walsworth cited a collaboration with the Harvard Center for Brain Science on nanoscale magnetic sensing as another case where new bioimaging tools are being developed by physical and life scientists working together.

"We plan to keep pushing the boundaries of what can be measured and imaged and then applying these new tools in both the physical and life sciences," Walsworth said.

Collaborations such as these, Rosen said, illustrate the benefit of working at a large research institution such as Harvard, where advances in one field can benefit other fields, even though they are seemingly unrelated.

"The interesting thing is all of these connections between basic physics, way-out cosmology, patient care, computers, and technology," Rosen said. "The same physics used to solve mysteries of the universe can be applied to these here-on-Earth problems."

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