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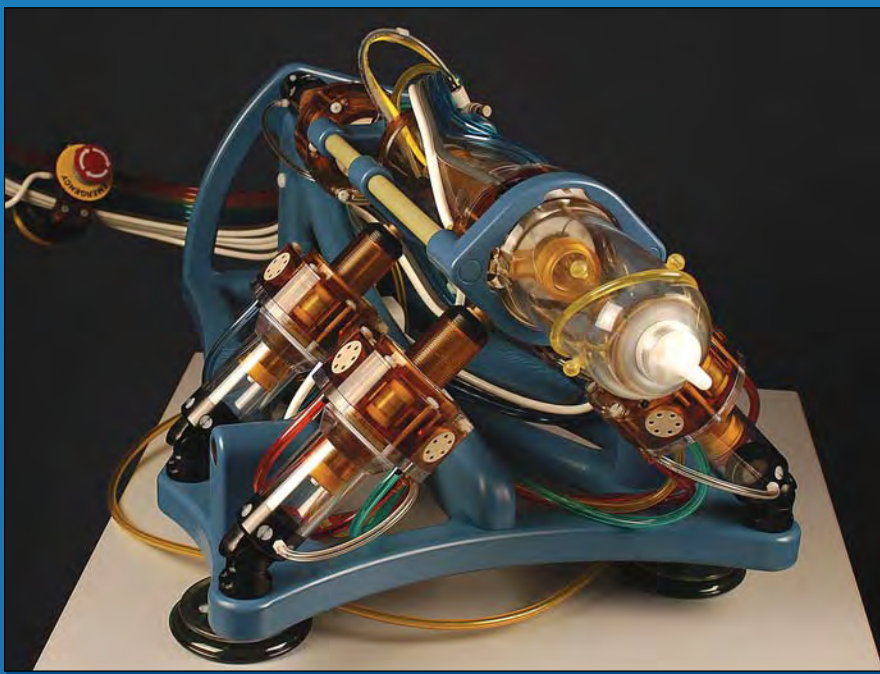

Image courtesy of Dan Stoianovici, Ph.D., The Johns Hopkins University

MR-Safe Motor Could Enable In-Scanner Interventions

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MR-Safe Motor Could Enable In-Scanner Interventions

A NEW NON-METALLIC, non-electric motor safe for use during MR imaging extends remote robotic hands to perform image-guided interventions within closed-bore high-field scanners.

The first application of the motor is for prostate needle interventions including brachytherapy and biopsy.

"Current needle interventions of the prostate systematically target regions of the gland but do not directly aim to imaged locations of abnormality," said lead developer Dan Stoianovici, Ph.D., an associate professor of urology and mechanical engineering at The Johns Hopkins University and director of the Urology Robotics Program of the Brady Urological Institute in the School of Medicine. "We have been working to create instruments that help physicians guide prostate procedures based on advanced imaging."

The motor, known as PneuStep, works with a new needle biopsy robot called MrBot to accurately target a tumor during MR imaging and obtain tissue samples. An article in the February 2007 issue of *IEEE/ASME Transactions on Mechanotronics* describes PneuStep.

Dr. Stoianovici said the four-year, National Institutes of Health-funded project to develop PneuStep and MrBot was extremely challenging. "Robots normally use components that are totally incompatible with MR," he said, referring to the electric currents and metal that interfere with the image.

Containing only plastic, ceramic, glass and rubber, the new motor consists of three pistons connected to a series of gears. The gears are turned by air pulses, which are in turn controlled by a computer located in a room adjacent to the MR machine.

"Using pneumatics was not simple either because it was not very precise four years ago when we began this research," said Dr. Stoianovici. "Our goal was to move the needle precisely—we had to make a lot of motor prototypes. It took three years to create our current motor and robot so that they can work inside the MR environment. This was very well invested time, because it is a unique and very enabling technology."

Never before has it been possible to perform precise motion at the isocenter of the highest field scanner without interfering with the image and in a manner entirely safe for the patient and personnel.

Dan Stoianovici, Ph.D.

Conquering MR Paves Way for Other Modalities

The robot goes alongside the patient in the MR scanner and is controlled remotely by observing the MR images. The motor is rigged with fiber optics, which feed information back to the computer in real time, allowing for both guidance and readjustment.

"The robot takes digital coordinates of the imaging abnormality and directs a needle precisely to that spot," said Dr. Stoianovici. "Humans are not digital devices. We have intelligence but robots can better understand the digits."

He said the prototype worked accurately in cadaver testing, always coming within just a millimeter of the target and, remarkably, without any trace on the image. Preclinical trials have shown, however, that the robot must be refined to improve ease of use and sterility. As the robot is designed right now, it is difficult to change needles from patient to patient. Additional testing for U.S. Food and Drug Administration protocols is under way with support from the Prostate Cancer Foundation and the Patrick C. Walsh Foundation.

Dan Stoianovici, Ph.D.
The Johns Hopkins University

Dr. Stoianovici said the first-of-its-kind, fully automated robot gets its uniqueness from the setting in which it was created. "Our lab has a very unusual look for a urology lab, with advanced design and manufacturing equipment that is very rare even in engineering departments," he said.

The appeal of the "MR stealth" motor, he added, comes not only from its ability to perform precise needle procedures with the robot under direct image control, but also to facilitate development of other interventional devices.

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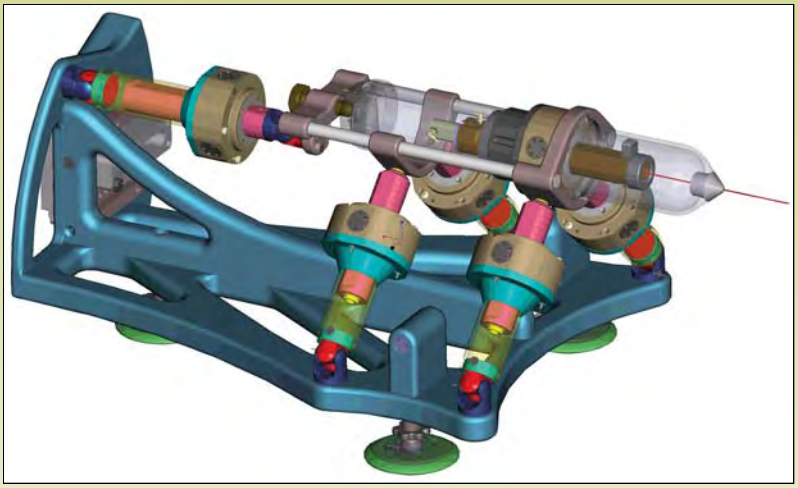

Computer-aided design rendering of the MrBot robot.

MrBot is a plastic, electricity-free robot. The robot is connected, with air hoses and optic fibers, to a control cabinet located outside the MR imaging room. The cabinet contains all control electronics and communicates with the robot through electro-optical and electropneumatic interfaces.

MrBot and male patient in a 3T closed bore MR imaging scanner.

out interfering with the image and in a manner entirely safe for the patient and personnel," said Dr. Stoianovici. Given that the MR imaging environment is the most challenging for compatibility with mechatronic devices, the invention of PneuStep is an important first step toward making multi-imager compatible instruments, he said.

Testing Under Way with MR Spectroscopy

Researchers are currently planning to use PneuStep and MrBot with multi-parametric MR imaging for targeted needle biopsies. The promise of a new MR-safe motor indeed lies alongside growing application of functional MR techniques like spectroscopy, diffusion-weighted imaging and dynamic contrast-enhanced MR imaging, which can augment conventional MR imaging of the prostate to provide more accurate diagnosis and staging of cancer, said Katarzyna J. Macura, M.D., Ph.D., an assistant professor in the Russell H. Morgan Department of Radiology and Radiological Science at The Johns Hopkins Medical Institutions and an MR expert in genitourinary imaging.

"The robotic devices provide a high degree of precision," said Dr. Macura, noting that this precision can be utilized for both diagnosis and the delivery of local treatments using heating or freezing techniques to replace radical therapies like surgery and radiation.

Spectroscopy assesses decreased citrate, the marker of normal prostate gland tissue, and elevated choline, the marker of tissue proliferation that occurs when cell membranes turn over in abundance, which occurs in tumors. Dynamic contrast enhancement or diffusion-weighted imaging evaluate tissue perfusion and water molecule diffusion at the cellular level.

"MR imaging over the decades has had its ups and downs as far as prostate cancer diagnosis is concerned," said Dr. Macura. "Today, more robust strategies allow us to improve spatial resolution and temporal resolution, and to apply new functional MR imaging parameters to detect cancer and guide tissue sampling. The paradigm is shifting from total prostate gland to intragland treatment options. In the future, we will see truly minimal interventions in prostate cancer treatment, for which precise tumor localization, biopsy and therapy delivery will be vital." □

Learn More

- An animation of the PneuStep MR-safe motor developed by researchers at The Johns Hopkins University is available at *urology.jhu.edu/urobotics/projects/PneuStep/*. An animation of an accompanying needle biopsy robot, MrBot, is available at *urology.jhu.edu/urobotics/projects/MrBot/*.