Integrating PET/MR

The first images combining PET and 3T MR images that emerged a couple of years ago united PET and MR images virtually. Today, a handful of researchers are using the first integrated PET/MR scanners that bring together two complementary techniques that might be more effective than each modality separately. A team at University Hospital of Geneva is using an integrated sequential PET/MR system (Philips) in staging prostate cancer, breast cancer and complex post-surgical evaluation of head and neck cancers. These patients might benefit from the hybrid scanner for a shorter single imaging procedure, says Osman Ratib MD, PhD, professor and chair of radiology, department of Medical Imaging and Information Sciences and head of nuclear medicine division who leads the team.

Contrary to PET/CT, where sequential scanning is the solution for image co-registration to correlate structural and functional information, simultaneous PET/MR has many additional features, says Habib Zaidi, PhD, head of PET instrumentation & neuro imaging laboratory, Geneva University Hospital, Geneva, and visiting professor at University Medical Center of Groningen, in the Netherlands. First, simultaneous scanning reduces study acquisition time and allows for scanning under the same physiological conditions. Second, high-field MR generates high-resolution anatomical and structural images offering better soft-tissue contrast resolution and a wide variety of tissue contrasts compared to CT. It allows functional MR imaging, enabling temporal correlation of blood flow with metabolism or receptor expression in brain studies. More importantly, it is capable of assessing flow, diffusion, perfusion and cardiac motion in one single examination. Third, MR can be combined with magnetic resonance spectroscopy to measure spatially matched regional biochemical content and to assess metabolic status or the presence of neoplasia and other dis-
cases in specific tissue areas. Finally, MR does not use any ionizing radiation and therefore can be used without restrictions in serial studies, for pediatric cases, and in many other situations where radiation exposure is a concern, explains Zaidi.

**Promising applications**

There are actually three flavors of PET/MR. The first type is a fully integrated simultaneous PET/MR system for the brain which has been available for a couple of years, explains Zahi A. Fayad, PhD, professor of radiology and medicine (cardiology) at the Mount Sinai School of Medicine and the director of the Translational and Molecular Imaging Institute and Mount Sinai Medical Center, New York City. The second one is a sequential system—a whole-body MR scanner and a PET scanner within the same room with a table that shuttles between the two systems. The systems are integrated within the same imaging acquisition console as well as the same room. The third type, which will be soon be available, is a fully integrated simultaneous whole-body PET/MR scanner. Siemens is expected to deliver a system of this type in the next 12 months, predicts Markus Schwaiger, MD, director of department of nuclear medicine and Dean of School of Medicine, Technische Universität München, Munich.

The Siemens integrated PET/MR scanner for imaging the brain has been used by Ciprian Catana, MD, PhD, instructor in radiology at Harvard Medical School and director of the Integrated MR-PET Core, Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Boston, and his group. Promising applications, he notes, include the assessment of brain cancer, neurodegenerative diseases, acute and chronic stroke. In addition, disorders associated with changes in mental status, including depression, dementia, schizophrenia, obsessive-compulsive disorders could be investigated in new ways. “We have started to use PET/MR for therapy monitoring in brain tumors. Using the advanced quantitative capabilities of the integrated scanner, our aim is to better understand the mechanism of action of therapeutic agents. We are also focusing on Alzheimer’s disease. In this patient population, simultaneous PET/MR measurements allow us to study the interrelation between structural, functional and metabolic changes in new ways,” he adds.

**Sequential PET/MR**

Sequential PET/MR system could have applications in whole-body imaging as well as neurology, oncology and cardiology imaging, says Fayad. His group at Mount Sinai uses sequential PET/MR in imaging atherosclerosis, oncology and the brain. “We are very much interested in atherosclerosis and using FDG-PET to look at inflammation deposit within the artery. We use PET to get the information on inflammation and MR to give us the vision of the anatomy as well as the other structural information and composition information,” says Fayad. There are a lot of applications related to cognitive function as well, in neurosurgery, neurology and psychiatry, he adds.

University Hospital Zurich is the first site installing GE’s integrated sequential PET/MR system, which will take place in the first half of 2011. “Integrated systems are favored by the fact that patients have to be up and downloaded only once,” says Gustav K. von Schulthess, MD, PhD, director, department of medical radiology, University Hospital Zurich. “From a cost and workflow perspective, integrated sequential two-room PET/MR systems are the most attractive because both scanners can be used in parallel. Furthermore, patients can be scanned independent of each other, helping the users to maximize the value of their assets.”

So where could PET/MR possibly replace PET/CT or even MR? “There is a general consensus that staging and follow up of prostate cancers and head and neck cancers as well as some complex extensions of breast cancers could clearly benefit from PET/MR,” Ratib says. “Presurgical planning as well as the assessment of response to treatment in brain tumors could benefit from PET/MR with some added value in patient comfort and efficiency compared to software fusion of images from two separate studies acquired at different points in time.”

**Promising future**

The experience with this first generation of scanners will define the future clinical applications, Schwaiger says. It will be most attractive for neuro-scientists, but may be clinically useful in oncology and cardiology. Clinical applications will focus on glioblastomas, benign brain tumors as well as in other tumor entities such as ENT (the ear, nose, pharynx, and larynx), sarcomas, bone metastases and gastrointestinal tumors.

As PET/MR moves from investigational into clinical use, Fayad predicts that people will start focusing on different applications and performing comparison and efficacy studies. Another challenge is to develop MR imaging protocols that are fast enough to provide whole body imaging at high resolution in reasonable amount of time that can be applicable in clinical routine, says Ratib. The next important thing will be to identify the clinical applications.

We truly stand on the threshold of PET/MR. Across the globe, only a handful of systems have been sited to date. Siemens has four brain imaging integrated PET/MR prototype scanners installed at University Tübingen in Germany; Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Boston; Institute of Neuroscience and Medicine, Research Centre Juelich, Germany; and Emory Center for Systems Imaging at Wesley Woods, Georgia, U.S. Investigational sites utilizing Philips PET/MR systems include the University of Geneva, Geneva, Switzerland; Mount Sinai Medical Center, New York City; and Forschungszentrum Dresden-Rossendorf (FZD), Dresden, Germany. And GE’s first integrated PET/MR system will be installed at University Hospital Zurich next year.

From the research point of view, there are many applications for simultaneous acquisition, but from clinical point of view it is still sequential, says Catana. Radiologists and nuclear medicine physicians need to work together to define objective guidelines for the clinical indications that will benefit from this technology, suggests Zaidi. As more clinical applications of the PET/MR emerge, its impact will extend beyond neuro imaging to oncology and cardiovascular imaging. PET/MR’s future is bright for sure, stay tuned.