Integrated PET/MR in Oncology

- Integrated PET/MR is a newly available imaging technique that includes a simultaneous whole body MR and PET examination.
- Integrated PET/MR avoids co-registration errors in image reconstruction due to differences in patient positioning and has potential for MRI based motion correction to improve registration in the upper abdomen.
- PET/MR is most likely to be advantageous for cancers that are now imaged with both PET/CT and MRI and in pediatric patients.
- If indicated, a focused regional MR examination can be added to the PET/MR protocol.

**Figure 1.** PET/MR and PET/CT images of a 55 yo M with FDG avid pleural-based mass (FDG PET fused over whole body STIR T2 weighted images). (A) PET/MR image of chest region demonstrates lymph node involvement (white arrow), lack of chest wall extension, and diaphragmatic extension (yellow arrow). (B) and (C) Corresponding images from a PET/CT examination. (B) FGD PET and (C) Corresponding contrast-enhanced FDG PET/CT images were insensitive to diaphragmatic excursion and were concerning for chest wall invasion.

Combined imaging that co-registers anatomic and metabolic data is well established in the form of PET/CT, which offers superior diagnostic performance to that of separately performed PET and CT scans. However, MRI is the modality of choice for the diagnosis and staging of many soft-tissue cancers, especially those in areas of complex anatomy, because of the superior soft-tissue contrast of this modality. Up until recently, the only way to render combined PET-MR images was to perform sequential scans and use software registration algorithms. However, differences in patient positioning and physiological movement can pose problems and lead to inaccurate registration.
Figure 2. PET/MR and PET/CT images of a 67 yo woman with left-sided breast cancer. Top row: MR, PET, and fused MR/PET images reveal multiple bony metastases, with concordance of all FDG avid T2 weighted MRI lesions. Lesions indicated with white arrows were not revealed by contrast-enhanced CT (bottom row) or bone scan (not shown). There was also a T2 weighted hyperintense focus (suspicious for metastasis) in the right ilium (yellow arrow) that did not demonstrate FDG avidity. Bottom row: Corresponding contrast enhanced FDG PET/CT CT images.

Integrating PET and MRI posed many more challenges than integrating PET/CT because a standard PET scanner is not compatible with the high magnetic field of an MR scanner and required considerable re-engineering. The Siemens PET/MR scanner, recently installed at the MGH, combines a high performance 3 Tesla clinical scanner and a state-of-the-art avalanche photodiode-based PET system installed within its gantry. At present, integrated PET/MR is FDA approved for clinical imaging, and is currently approved at MGH for clinical research. It is anticipated that it will be available for clinical management of patients early next year.
Applications in Oncology

PET/MR is most likely to be beneficial for patients who currently receive both MR imaging and PET/CT. Because of more precise co-registration, PET/MR may have advantages in four groups of patients: (1) those with tumors in regions of complex anatomy, such as the pelvis and head and neck, in whom the invasion of cancer may be more precisely determined; (2) those with tumors that have poor contrast on CT, such as those in the liver and brain; (3) pediatric cancer patients, in whom it is important to minimize radiation exposure; and (4) those who have widely distributed tumors, such as lymphoma, because MR/PET will avoid the relatively large exposure to radiation of whole body CT.

PET/MR Image Acquisition

The PET/MR examination includes fast whole-body T1 and T2 contrast scans yielding high quality images. If more precise imaging is required for greater anatomical detail, additional tailored MRI can be added to the basic set of images. PET data acquisition occurs simultaneously. Patients are allowed to breathe freely throughout the examination. While this may result in some blurring of the images, registration of PET and MR images in a tailored MRI should be equivalent to CT as they are both breath hold techniques. However, imaging techniques that use MR to detect motion and can correct for motion in the PET images are in development and have been applied in preclinical studies.

In PET/CT, a low-dose CT scan is used for attenuation correction of the PET data. In PET/MR, this is replaced by a short Dixon MRI sequence, which estimates the distribution of four tissue types (fat, soft tissue, lungs, and background/air) that are used to generate an attenuation map, based on the presumed radiodensity of these tissue types. In direct comparisons with PET/CT, the standard uptake value (SUV) from PET/MR has been shown to be slightly different than but proportional to that from PET/CT.

The basic PET/MR scan is completed in about 45 minutes. If a focal scan of a particular body area is needed, that adds about 15 minutes to the examination.

Limitations

Contraindications to PET/MR are the same as the standard ones for MRI. However, fewer metallic implants have been tested at 3 Tesla than at 1.5 Tesla. Metal artifacts are greater when imaging at the higher field strength and are more limiting than those seen in PET/CT. Metal artifacts can also affect the accuracy of attenuation correction.

The field of view of the PET camera is 60 cm, which can be limiting for examinations of obese patients. Whole-body MRI requires multiple coil elements to be placed, which some patients find confining.

Scheduling

At this time, PET/MR is strictly under the auspices of research and cannot be used to manage patients. If a patient is interested in getting a research PET-MRI, the following protocols are open: (Catana 2011P001814; 2011P002136 & El-Fakhri 2012P000697). For more information, please call 616-643-4885. By the first quarter of 2013, scheduling will likely be possible through the Radiology Order Entry system, http://mghroe. The exams are performed at the Athinoula A. Martinos Center for Biomedical Imaging, Building 149, Charlestown Navy Yard.

Further Information

For more information about MR/PET imaging, please contact Alexander Guimaraes, MD, PhD, Abdominal Imaging and Intervention, Massachusetts General Hospital, 617-726-9357, or Dr. Ciprian Catana, MD, PhD, 617-643-4885. Alternatively, please contact MR/PET specialists Subba R. Digumarthy (Chest Imaging), Michael S. Gee, MD, PhD (Pediatric Imaging), Mykol Larvie, MD, PhD (Neuroimaging), or Umar Mahmood, MD, PhD (Nuclear Medicine and Molecular Imaging).

We would like to thank Alexander Guimaraes, MD, PhD, Ciprian Catana, MD, PhD, Bruce Rosen, MD, PhD, Martinos Center for Biomedical Imaging and Umar Mahmood, MD, PhD, Georges El Fakhri, PhD, Nuclear medicine and Molecular Imaging, for their assistance and advice for this issue.
References


