Integrating PET or SPECT with MRI: How, Where, and Why?

S. Cherry[1]

[1]Biomedical Engineering/Center for Molecular and Genomic Imaging University of California, Davis, Davis, CA, United States

The suggestion of integrating PET and MRI into a single imaging platform has been around for many years, but a recent surge of research activity, catalyzed by the clinical success of integrated PET/CT scanners, new photodetector technologies for PET, the growth of the field of in vivo molecular imaging and an increasing appreciation for the power of multimodality imaging, has now clearly demonstrated the feasibility of simultaneous PET and MR imaging. The technology is also transferring to the industrial sector, and first commercial PET/MRI prototypes for human imaging are expected to be delivered during the course of 2007. The purpose of this plenary lecture is to review the different approaches being taken to multimodality PET/MRI instrumentation and to discuss the strengths and limitations of different approaches. Early examples of simultaneously acquired in vivo PET and MRI images will be shown.

Motivation for PET/MRI: There are numerous clinical and preclinical applications where MRI is the modality of choice for anatomic imaging due to its excellent soft tissue contrast. Furthermore, this anatomic information, is provided without the radiation dose associated with CT. More interestingly, from a research perspective, are the opportunities to temporally correlate dynamic MR imaging or spectroscopy with dynamic PET imaging, allowing multiple physiologic, functional, metabolic or molecular measures to be observed with corresponding anatomic localization. If simultaneous imaging with PET and MRI is feasible, it combines two extraordinarily powerful imaging tools in a spatially and temporally synchronized coordinate system and perhaps allows the exquisite spatial resolution of MRI and sensitivity of PET to be exploited in a synergistic fashion.

Challenges for PET/MRI: PET/CT scanners are built in a tandem configuration in which PET and CT scans are acquired sequentially. Because the two scanners are axially displaced from each other, no major modifications to the hardware were necessary to make it work. For PET/CT, this arrangement makes sense, as the CT scans are generally acquired in a fraction of the time required for PET, and the CT is purely used for anatomic imaging. But to capture the full potential of PET/MRI outlined above, most investigators have concluded that it is necessary to acquire PET and MRI data simultaneously, or at least in very rapid succession. This requires that the PET scanner be integrated within the magnet, and leads to many technical challenges, including concerns regarding electromagnetic interference, susceptibility artifacts, eddy currents, and the magnetic field sensitivity of PET detector technology.

Approaches to PET/MRI scanners: Several different approaches are being pursued to develop integrated PET/MRI scanners. One of the most popular approaches utilizes PET detectors consisting of avalanche photodiodes (APDs) that are placed within the bore of conventional MRI magnets and coupled to scintillator crystals. The APDs are magnetic field insensitive, and it has been shown, with appropriate shielding, that PET and MRI images can be acquired simultaneously with this approach (Figure 1). Alternative approaches include the use of long optical light guides to pipe the light from scintillation crystals to photodetectors that reside outside the bore of the MRI scanner, the use of novel split-magnet designs that provide space for a large number of PET detector modules, and the use of field-cycled MRI systems.

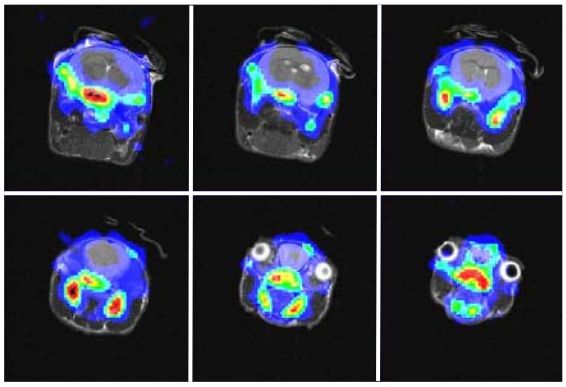

Figure 1: Simultaneous PET and MRI images from a proto-type MR-compatible PET scanner developed at UC Davis.

Current Status: Several of the development efforts have resulted in working systems that produce PET and MR images simultaneously. Much work is in progress to quantitatively characterize interference effects between the two systems and any degradation caused in either set of images. Nonetheless, the early data clearly indicates that simultaneous PET and MR imaging is feasible without large-scale artifacts for common data acquisition protocols.

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