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Simultaneous PET/MR Imaging - Key Benefits

Integrated PET/MR imaging scanners capable of simultaneous data acquisition are now available for human use. A report published by Ciprian Catana, MD, PhD (Athinoula A. Martinos Center for Biomedical Imaging) says the synergistic use of the simultaneously acquired datasets is expected to benefit numerous research and clinical applications.

See Also: Cancer Imaging: The Need to Improve Utilisation Management

PET can assay with high molecular sensitivity a wide range of biological processes (from tracking the in vivo distribution of small molecules to cells) using radionuclides that decay by positron emission. However, PET has limited spatial resolution, and most often the images lack the anatomic detail required for clinical interpretation. On the other hand, MR imaging provides high spatial resolution anatomic images with excellent soft tissue contrast even using routine techniques. More advanced MR sequences exploit other sources of endogenous contrast to study physiology (e.g., water diffusion), function (e.g., blood oxygenation level–dependent contrast), and metabolism (e.g., relative concentration of various metabolites).

In those patients requiring both examinations, the simultaneous acquisition could improve the spatial registration between the two images and the workflow and increase the patient's comfort.

PET/MR imaging would have likely failed to transition from small-animal to human imaging if it were not for the emergence of MR-compatible photon detector technology that allowed the placement of the PET detectors inside the magnet's bore. Avalanche photodiodes (APDs) were the first such photon detectors that were found to work even inside ultra–high-field magnets. This technology allowed Siemens to build the first PET/MR imaging prototype scanner (BrainPET) for human brain imaging. More recently, Geiger mode APDs (also called solid-state photomultipliers or silicon photomultipliers [SiPMs]) have emerged as promising candidates for replacing APDs.

To enable simultaneous acquisition, the MR radiofrequency coils have to be positioned in the PET field of view and thus contribute to photon attenuation.

Whole-Body Imaging

Siemens was the first to introduce a fully integrated whole-body integrated scanner, called Biograph mMR, in 2010. The scanner can acquire list mode data in 3-dimensional mode. The PET images can be reconstructed using either the filtered back projection or the 3-dimensional ordinary Poisson ordered-subset expectation maximisation algorithm. In 2013, General Electric introduced the first whole-body SiPM-based integrated PET-MR imaging scanner called SIGNA PET/MR.

On the Biograph mMR, the attenuation correction is performed using the MR data acquired with a 2-point Dixon volume interpolated breath-hold examination MR sequence. In-phase, out-of-phase, water, and fat images are generated at each bed position and combined to generate the corresponding whole-body images. Similarly, on the SIGNA PET/MR scanner, the attenuation information is acquired using a liver acquisition with volume acquisition-flexible (LAVA-Flex) scan.

The major difference between these two PET/MR scanners is that the SIGNA PET/MR scanner has TOF (time-of-flight) capability. The main advantage of incorporating the TOF information is that the signal-to-noise ratio improves compared with the non-TOF images.

Several recent studies found the TOF can reduce the effect of inconsistencies between the emission and attenuation data, such as those encountered in MR-based attenuation correction caused by bone or lung tissue misclassification, incomplete attenuation maps caused by truncation, or implant-related signal voids.

Promising Research and Clinical Applications

The simultaneous acquisition would allow the cross-validation of different techniques that have been proposed to measure various biological processes. As an example, cross-validating cerebral perfusion measurements could benefit stroke patients.

In addition to evaluating changes in metabolism and anatomy in the study of normal and diseased brain, PET/MR imaging allows the simultaneous assessment of brain neurochemistry and activity. For example, the interaction between dopamine signalling and neural networks changes during working memory was investigated in a recent study.

In the assessment of oncologic patients, the synergistic use of imaging biomarkers reflecting changes in anatomy (from MR imaging) and metabolism (from PET) has the potential to increase confidence in equivocal cases both at the initial staging and during follow-up. PET/MR imaging will likely be the modality of choice in areas of the body in which CT is suboptimal for providing anatomic correlates to the PET metabolic measurements because of the poor soft tissue contrast such as head and neck.

Source: Magnetic Resonance Imaging Clinics of North America
Image Credit: MR Solutions

Published on : Tue, 18 Apr 2017