First PET images using a prototype small animal field-cycled MRI/PET imaging system

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Introduction: Field-cycled MRI (FCMRI) is one of several possible approaches to combined Positron Emission Tomography (PET)/MRI. Field-cycled MRI uses two resistive magnets in place of the single superconducting magnet [1-2]. Field-cycled systems have greater geometric versatility as compared to traditional MRI, allowing the design of an open bore configuration relatively easily, in addition to providing full dynamic field control. The performance of conventional photomultiplier tubes (PMTs) in dynamic field sequences relevant to field-cycled MRI has been studied previously [3] and it was demonstrated that full recovery to normal performance occurs within 2~3 ms following removal of magnetic fields. In this abstract, we present the first PET images obtained within a combined field-cycled MRI/PET system constructed within our labs.

Methods: A partial PET ring was built and inserted into the gap within a field-cycling magnet system. Four Anger-logic based PET detector blocks were salvaged from a Siemens whole body PET scanner and used to form the partial ring. The PET system diameter was 200 mm and the BGO ($Bi_4Ge_3O_{12}$) scintillator pitch was 6.5 x 5.5 x 30 mm. The magnetic field system had an efficiency of 1.42 mT/A and provided up to a maximum of 45 mT for this experiment. A parallel IGBT circuit was used to generate the dynamic magnetic field waveforms (0.36 T/s), which simulated operation of the field-cycled MRI system (**Figure 1**). PET images were acquired for a phantom consisting of three ^{22}Na radiation point sources, each of 2 μCi activity. The three point sources were equally separated by 10 mm. The samples were mechanically rotated within the bore over time, in order to obtain the required number of view angles for image reconstruction. The trigger for PET acquisition was 650 ms in duration and started 10 ms following the end of each magnetic field pulse. The total imaging time was 6 hours, yielding a total number of counts for each PET image of approximately 3e5. Separate images were acquired using the PET system both inside and outside the MRI system. The PET image was reconstructed using a simple filtered back-projection algorithm. No attenuation or scatter corrections were made. The spatial resolution was quantified in terms of the average measured full-width-half-maximum (FWHM) of the image peaks corresponding to each point source.

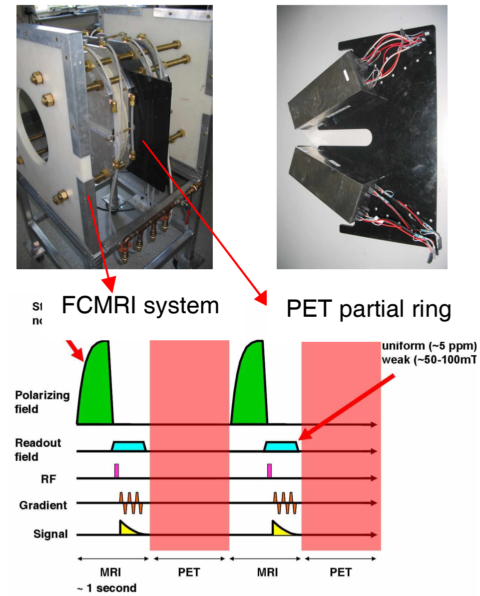

Figure.1: (**Top**) The prototype PET/FCMRI system. In a FCMRI, the main superconductive magnet is replaced by two resistive magnets: a polarizing magnet and a read out magnet. Only readout magnets are shown. The PET detectors are inserted directly around the isocenter. Four PMT-based PET detector blocks were used. (**Bottom**) The interleaved operation mode for PET/FCMRI system. PET detection is conducted during the intervals between successive magnetic field pulses.

Results: The images for both the PET system and the PET/MRI prototype system are shown in **Figure 2**. In both cases, the three point sources can be resolved. The spatial resolution for the PET system alone was 8.6 ±0.5 mm (pixel width: 1.4 mm). This is comparable to resolutions for other PET systems using similar detector and scintillator configurations [4]. The spatial resolution of the combined PET/MRI prototype system was measured to be 8.7 ±0.7 mm. No significant degradation of PET image quality due to the existence of the dynamic magnetic field pulses was observed.

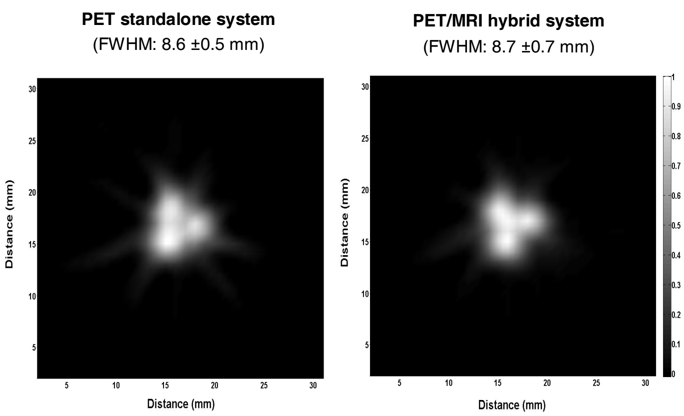

Figure. 2: PET images for both configurations reconstructed using filtered-back-projection methods. Color bar represents the normalized pixel intensity. No attenuation or scatter corrections were made. No significant degradation of PET image quality, in terms of FWHM, is observed for the combined PET/FCMRI system.

Discussion: This work supports the hypothesis that a PET/MRI dual modality system using conventional PMT technology can be achieved using a field-cycled MRI architecture. The relatively poor PET spatial resolution obtained is due to the fact that whole-body PET detector components were used, which introduces significant parallax error and limited sampling in our small diameter animal-scale system [4]. Based on the results of this preliminary study, we are working towards the development of a complete small animal PET/MRI system based on the field-cycled MRI architecture and traditional PMT-based PET detector elements.

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