Magnetic Field Exposure Tests on a Siemens Inveon Small Animal PET System: A Feasibility Study for Multimodality PET and Field-Cyled MRI

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Introduction

Combining PET with MRI in a hybrid system offers several advantages over PET/CT, namely significantly better soft tissue contrast & resolution and radiation dose reduction for longitudinal studies. Combining conventional PET and superconducting MRI faces many technical challenges, especially the incompatibilities between photomultiplier tube-based (PMT) PET detectors and high magnetic fields [1].

One approach to PET/MRI is to use field-cycled (FCMRI) with a conventional PMT-based PET system [2]. Combining PET with FCMRI would enable the use of commercially available, highly optimized PET systems with little physical modification. The authors have designed a docking PET/FCMRI system specifically based on the Siemens Inveon small-animal PET (Siemens Medical, Knoxville, TN). For this approach to be feasible, the PET detectors must experience no permanent changes in gain or efficiency after exposure to magnetic fields. In this abstract, the authors present data from a preliminary feasibility study to test the robustness of the PET system after exposure to magnetic fields.

Methods

In FCMRI, a resistive electromagnet generates the main magnetic field and can easily be turned on or off. With the main fields on one can perform normal MR imaging, and, in a small fraction of a second, the main fields can be completely turned off. A fully functional FCMRI system has been built (Figure 1) [3]. Proof-of-principle tests have shown that linear and mesh PMTs recovered normal operation within several milliseconds of the field being turned off with no long-term effects [2]. In addition, the authors have shown that PMT-based PET systems can operate sequentially with an operational FCMRI system [4].

The authors are developing a PET/FCMRI system for small-animal imaging. A Siemens Inveon PET system has been acquired and installed within our labs. The detector consists of a ring of 16 PET modules, with each module having a row of four LSO crystal blocks (1.59x1.59x10 mm crystals in 20x20 block) coupled to four position-sensitive PMTs (Hamamatsu R8900). The Inveon system permits fast scanning due to its very high sensitivity (10%) and has a large axial FOV (12.7 cm) enabling whole-mouse imaging.

The PET system was positioned close to the FCMRI system with the field off. The closest PMT was 101 cm axially from the center of the MRI bore. The axis of the PET system was offset 10 cm below the axis of the MRI system to ensure maximum magnetic field magnitude within the topmost PET module. Position reproducibility and count-rate experiments were performed on the PET system before and after exposure to magnetic fields to test changes in gain and efficiency, respectively. For position measurement, a 300-μm point source (Na-22, 0.57 MBq) in a 1 cm^3 plastic cube was affixed to the PET bed and moved to the isocenter. PET data were collected for 5 minutes and the image was reconstructed using filtered back-projection. A 3D Gaussian function was fitted to the point-source activity to determine the coordinates of the mean. To measure count-rate, a diffuse cylinder source (Ge-68, 4.4 MBq, r = 3 cm, h = 16 cm) was positioned at the isocenter and a 5-minute acquisition was taken recording the number of coincidence events. Two acquisitions were recorded for position data and three acquisitions for count-rate. The phantoms are shown in Figure 2.

The FCMRI system was energized for 4 min producing a pulsing field of amplitude 11±1 mT within the topmost PET module. The PET measurements were repeated immediately after exposure. Before each PET scan, the temperature of the detectors was measured to be 35.0±0.5°C corresponding to an potential variation of ± 0.65% in count-rate measurements due to the temperature dependence of LSO luminous efficiency (-1.3%/°C) [5].

Results

The results of the position reproducibility and count-rate experiments are reported in Table 1. The coordinates of the peak position experienced a statistically significant change after magnetic field exposure, suggesting a possible change in PMT gain values. The bed motion precision (30 μm) cannot account for the magnitude of this change. However, since the optimal imaging resolution of this PET system is greater than 1 mm, a shift of less than 0.2 mm is of little significance. The normalized count-rate increased by 0.72% after exposure. It is possible to explain this increase in efficiency by a 0.6 °C decrease in detector temperature, within the uncertainty of the experiment.

Discussion

A larger-scale FCMRI system (Figure 3) is under development for docking with the Inveon PET system [6]. At 32-kW-continuous operation, the main magnet produces 0.5 T. The length, diameter and mass of the system are 72.5 cm, 61 cm and approx. 900 kg, respectively. Based on the magnitude of the field used in this feasibility study, the results suggest that the gap between the PET system and the new FCMRI system can be 60 cm or more to ensure no significant permanent affects on PET imaging when the magnet is not energized. The authors believe the two systems can be placed closer and will conduct further tests at higher field strengths to verify this.

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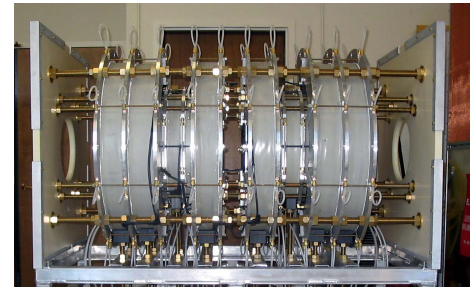[6] Bindseil, G., *et al.* 17th ISMRM. (2009) **3089**

Figure 1. Field-cycling MRI system used to generate magnetic field in this experiment.

Figure 2. Photographs of diffuse source (top) and point source (bottom) on PET system bed.
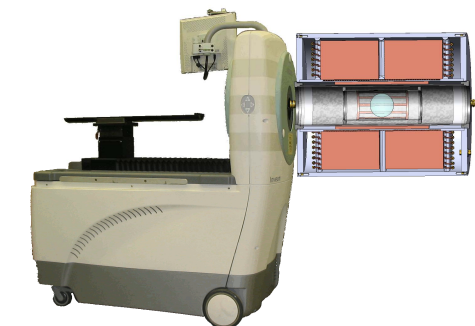

Figure 3. Docking geometry of the proposed PET/FCMRI system. An extendible bed moves between PET and MR imaging regions with 30-micron precision.

Table 1.
Position Reproducibility and Count-Rate Before and After Magnetic Field Exposure

	Before	After
Position (± 0.003 mm)		
X	65.373	65.336
Y	71.920	71.980
Z	82.173	82.350
Coincidence Events* *(± 0.0003×10^7)*		
	2.9703×10^7	2.9918×10^7

*Normalized to account for decrease in activity