Hybrid PEM/MRI, a new approach for high resolution breast imaging

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Introduction and purpose: Molecular imaging with ^{18}F-fluorodeoxyglucose (FDG) became a valuable tool for breast cancer detection. Although positron emission tomography (PET) is able to track radiolabeled biomarkers with a high sensitivity down to sub-picomolar concentrations, it cannot render structural information. A practical solution for this problem has been combining PET with other anatomical imaging techniques such as X-ray CT, making PET/CT a valuable imaging tool completely integrated in the routine clinical practice. However, CT has its own disadvantages especially its high radiation dose and low soft-tissue contrast. In the last decade, considerable efforts have been made to combine Magnetic Resonance Imaging (MRI) with PET as an alternative to CT [1]. Unlike CT, MRI provides high soft-tissue contrast and does not require any ionizing radiation. Thus, combining PET and MRI seemed very suitable for molecular & anatomic imaging with high resolution. On the other hand, clinical studies using whole-body positron emission tomography (PET) showed that this technique suffers from low sensitivity for early stage of breast cancer due its degraded spatial resolution [2-3]. As a solution, dedicated breast imaging systems, Positron Emission Mammography (PEM), have been introduced. PEM performs breast imaging under gentle compression [4]. Therefore, it allows good immobilization of the breast and assure a small interdetector distance realizing the highest spatial resolution and best signal to noise ratio (SNR) due to efficient count collection configuration [5-6]. Indeed, combining PEM and MRI remains a challenging task due low performance of the photomultiplier (PMT) based standard PEM detectors in high magnetic fields.

Method: In this study, we test the performance and reliability of our hybrid PEM/MRI system on a phantom mimicking compressed breast. The hybrid system uses two PEM detectors that are positioned on the opposite side of the phantom inside the MRI bore. Each detector has an active area of 44x44 mm^2, and is composed of a 16x16 lutetium oxyorthosilicate (LSO) crystal array in front of a 6x6 Silicon PMT array. The PEM detectors are used as two compression paddles performing volumetric measurements on the immobilized breast. This detection configuration would achieve a high resolution imaging due to the reduction of motion effects. A highly pure copper is used to shield the detectors and the connection cables with the charge-sensitive preamplifiers in order to avoid the noise induced by the RF signals. Figure 1.a shows a picture of the setup outside the MRI bore. The rectangular breast phantom has the dimensions of 50.9 x 94.6 x 87.3 mm^3 (X, Y, Z) and contains a 10 mm diameter cylinder, used as a target. The target is positioned at the center of the phantom and oriented along its z-axis, Fig 1.b. First the phantom was filled with water and the target with 109.38 μCi of FDG to mimic an ideal FDG accumulation at the tumor site. Second, the background was filled with 1:10 FDG solution to mimic the presence of background radioactivity. The study was performed on a clinical 3T MRI scanner (Philips, Achieva) equipped with a breast coil (SENSE-Breast-4). The MRI data acquisition was achieved with a standard MRI spin-echo sequence using TR=423.9 ms, TE=8.7 ms. The MR images were acquired in a 512 x 512-pixel matrix with a pixel size of 3x1x1 mm^3.

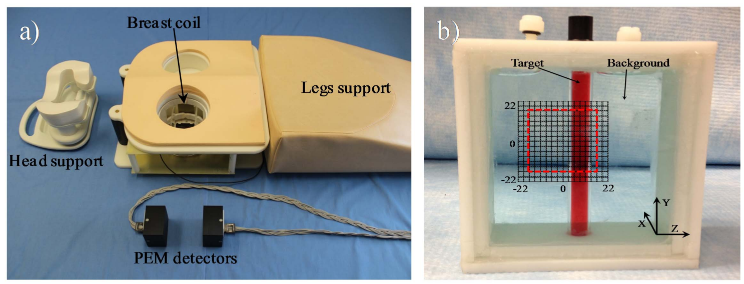

Figure 1. Side view of: a) the setup outside the MRI bore, b) the phantom and the position of the detectors on its both sides. The center of coordinates is chosen to be at the center of the detectors.

Results: To quantify the influence of the presence of the PEM detectors on the MRI image quality, the SNR of the T1 weighted images are measured with, then without the presence of the PEM detectors inside the 3T bore. The SNR decrease by 70% due to the presence of the PEM detectors. On the other hand, the influence of the magnetic field on the performance of the PEM detector is evaluated using the normalized position and the full width at half maximum (FWHM) of the 511 keV peak. After placing the detectors inside the 3T magnetic field, we noticed a shift of the normalized position of the peak by 1.3 and an enlargement of the FWHM by 44%. Since the performance of the PEM detectors decrease towards the edges of the detector, only events occurring in the effective area (34x34 mm^2) are taken into account, outlined with a red dashed line in Fig. 1. Using 1 mm^2 bin size and full 3D binning of the data inside the effective area, a 34x34x1156 bin^3 sinogram has been obtained. The PEM images are reconstructed using Maximum Likelihood Expectation minimization (MLEM) algorithm in twenty iterations. They are first reconstructed without, then with the structural MR priori information, Fig 2. During the first experiment, the reconstructed images without the MR priori show a degraded image quality in the XZ and YX directions due to the PEM acquisition configuration. This problem is alleviated when MR priori is used. Table 1 summarizes the mean and standard deviation computed on the target (T) and the background (B), for the PEM images reconstructed with and without MR priori information.

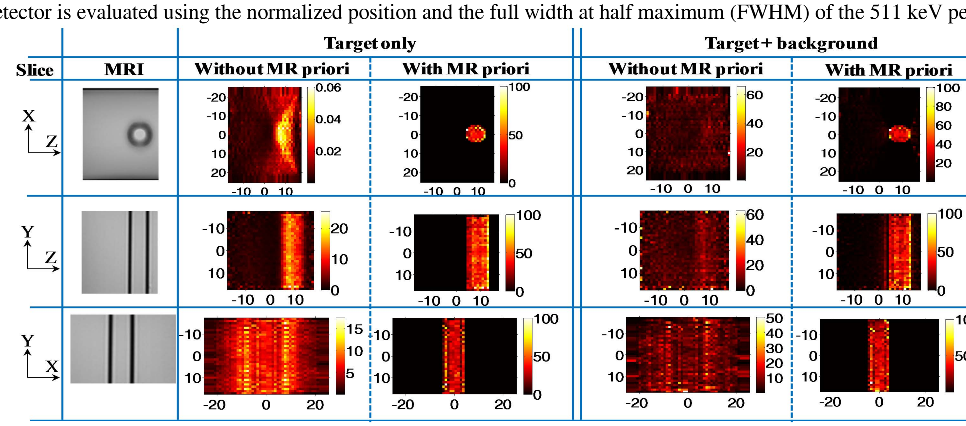

Figure 2. The first column shows the MRI images of the compressed breast phantom. The PEM images are reconstructed with and without MR a priori information. The 2nd and 3rd columns present results obtained when only target is hot while 4th and 5th columns present results obtained when background also contains 1/10th of target activity.

Conclusion: We have built a hybrid PEM/MRI breast system using silicon photomultiplier. We have tested its performance with compressed breast mimicking phantom. Our results show that utilizing MR priori information improves the PEM reconstruction drastically and provides superior PEM results. We have tested our system with and without activity in the background. Our future work focuses on development of a clinical PEM/MRI system for breast imaging and reduction of the total imaging time by simultaneous acquisition of nuclear and MR images.

	Without MR priori			With MR priori		
	T	B	T/B	T	B	T/B
T	6.4±2.9	1.7±1.6	3.7	27.9±14.9	0.0±0.0	/
T+B	5.9±3.1	4.2±3.4	1.4	22.8±12.7	1.8±1.3	12.6

Table 1: The mean and standard deviation computed on the target (T) and the background (B).

References: [1]. Pichler et al. J Nucl Med 2006; 47:639–647. [2]. Wahl RL. 2001; 36:250–60. [3]. Hodgson et al. J Clin Oncol 2008; 26:712–720. [4]. Berg et al, The Breast 2006; 12:309–323. [5]. Hoffman et al, J Comput Assist Tomogr 1979; 3:299–308. [6]. Budinger TF. Semin Nucl Med 1998; 28:247–67.