Functional Imaging Capabilities of a Combined Animal PET/MR System

H. F. Wehrl[1], M. S. Judenhofer[1], D. F. Newport[2], C. Catana[3], M. Becker[4], S. Widmaier[4], S. R. Cherry[3], R. E. Nutt[2], C. D. Claussen[1], and B. J. Pichler[1]

[1]Laboratory for Preclinical Imaging and Imaging Technology, University of Tuebingen, Tuebingen, Germany, [2]Siemens Preclinical Solutions, Knoxville, TN, United States, [3]Biomedical Engineering, University of California, Davis, CA, United States, [4]Bruker BioSpin, Ettlingen, Germany

Introduction:

The combination of positron emission tomography (PET) and x-ray computed tomography (CT) has shown the importance of multimodality imaging. However, especially in small animal research, the combination of magnetic resonance (MR) imaging and PET would be advantageous to gain highest soft tissue contrast from MR and eliminate additional radiation dose from the CT. Thus, our group has designed and built a MR compatible PET insert for the 7 Tesla ClinScan (BRUKER, Germany). The PET insert is based on 10 detector modules, each consisting out of a 3x3APD array coupled to a 12x12 array of lutetium-oxyorthosilicate scintillation crystals. The 35mm quadrature whole body mouse coil (BRUKER) is located inside the 6 cm bore of the PET insert which is located inside the gradient-coil of the MR scanner. This paper investigates the potential limitations of the combined system to perform MR imaging with focus on sequences used for functional MR imaging (fMRI), and spectroscopy. Since temporal stability during an fMRI experiment is of importance, an evaluation of our scanner performance with the PET insert built into the magnet was performed. Beside fMRI and spectroscopy performance tests, first simultaneous acquired in-vivo PET and MR images of a mouse are presented.

Methods:

Standard MR sequences: A cylindrical phantom filled with NaCl was imaged with standard spin echo (SE), turbo spin echo (TSE) and gradient echo (GE) sequences, while the PET insert was built into the MR system. Signal to noise and homogeneity of the phantom were calculated.

MR Spectroscopy: For evaluating the influence of the PET insert on MR spectroscopy, we performed a phantom study using a 15 ml Falcon tube filled with isotonic NaCl and 140 mmol citrate. The 35 mm quadrature coil was used and spectra were acquired with standard sequences using a TR=1500 msec, TE=7 msec, flip angle 90 degree, 4 averages, and water suppression. An isotropic voxel size 4.4x4.3x4.3 mm (0.8 ml) and the automatic shimming procedure of the system were chosen. Measurements were performed with and without the PET insert. After the usual post processing steps, the full width half maximum (FWHM) of the citrate peaks were measured and in addition a visual inspection of the baseline was performed.

fMRI/echo planar imaging (EPI): To test the fMR imaging capability (like BOLD sequences) of the combined PET/MR scanner, we performed measurements with the PET insert in the magnet powered on and off. Data were evaluated according to an adapted "BIRN" protocol as described by Friedman et al. which asses the temporal MR system stability. The phantom used for the measurements was a 15-ml falcon tube (diameter 17mm) filled with a solution that mimics the physiological properties of the mouse brain (H_20 bidest, $CuSO_4$ x $2H_2O$ 1g/l, NaCl 4.31 g/l). Since the intention of this procedure was to measure the stability of the scanner under conditions that are as close as possible to those of typical fMRI experiments, the following EPI imaging protocol were used: transversal slice orientation, 25x25 mm field of view (FOV), 5 consecutive slices, 2 mm thick, TR 2000 msec, TE 30 msec, Flip angle 90 degrees, bandwidth 2298 Hz/Pixel, 200 collected volumes, scan time 6min 44 sec.

Simultaneous in-vivo PET/MR imaging: First simultaneous in vivo PET and MR data were acquired with a C57BL/6 mouse injected with 580 µCi of the dopamine transporter ligand [C-11]Methylphenidate. PET data were collected dynamically over 60 min. During the PET acquisition MR images have been acquired using different TSE (TR = 2770; TE = 42; 4 aver.; 256 x 256 matrix; 1mm slice thickness) sequences. PET data were normalized and reconstructed using filtered back projection in a 128 x 128 image matrix. Images were fused using ASIPro software (Siemens Preclinical Solutions, USA). Time activity curves of the striatum and cerebellum were calculated.

Results and Discussion:

The measurements of the cylindrical NaCl phantom placed inside the PET/MR scanner showed no major degradation of the signal to noise ratio or the homogeneity when using various standard MR sequences, compared to tests performed without the PET insert. The spectroscopy of a citrate phantom showed no significant difference in the full width at half maximum (FWHM) of the citrate peaks when used with and without the PET insert or with the PET insert powered up. The FWHM measured to be approximately 4 Hz in each case. A visible inspection of the baseline of the spectra showed no distortions due to eddy currents or other adverse effects. The results of the evaluation of the fMRI measurements according to a "BIRN" protocol are shown in Table 1. The results show, that there is no considerable difference between the EPI imaging states of the system when the PET insert is switched on or off. The overall noise and SNR performance is comparable to other standard MRI systems. The mean EPI images in Fig. 1 show no visible image distortion due to the PET insert. A slightly higher drift of the mean value over time was observed which may be caused due to the increase in temperature when the PET insert is powered up. However for BOLD imaging this can be compensated by the fMRI data post processing. Figure 2 shows the simultaneous acquired PET and MR images of a mouse injected with [C-11]Methylphenidate. The PET images show clear uptake in the striatum of the brain and align very well with the corresponding MR images. Time activity curve show increased binding of the tracer to the striatum versus the cerebellum.

	PET Insert on	PET Insert off
SNR (central ROI, green)	315.7	329.1
SFNR (central ROI, green)	315.4	317.6
Weisskoff radius	4.56	4.66
RMS stability	0.0698 %	0.0695 %
BG intensity (bottom ROI, red)	1.12 %	1.10 %
BG intensity (left ROI, blue)	0.38 %	0.40 %

Table 1: Results of the "BIRN" evaluation performed on a series of 200 acquired EPI images with the PET insert powered up and off.

Conclusion

Our results show that the PET insert is fully functional inside the 7 Tesla ClinScan system. Fruthermore we showed that spectroscopy and fMRI using EPI sequences are possible not influenced by the PET insert. This paves the way to simultaneous functional imaging using fMRI, spectroscopy, and PET.

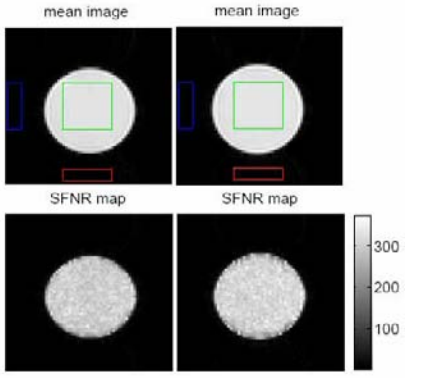

Fig. 1: (top) mean EPI images and respective regions used for evaluation. Bottom images show the functional noise maps. Left: PET insert on. Right: PET insert off.

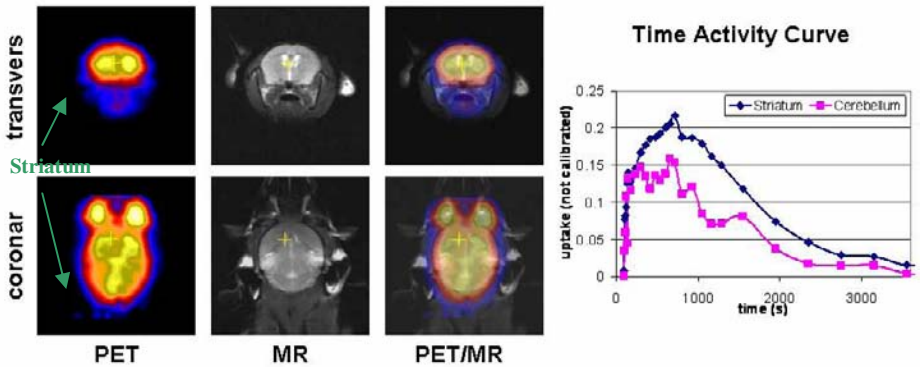

Fig. 2: (left) Transversal and coronar PET, MR and fused PET/MR images of a mouse injected with [C-11]Methylphenidate and scanned over 60 min. Time activity curves (right) of striatum and cerebellum show the specific binding of the tracer in the striatum.

References: L. Friedman, G.H. Glover: Report on a Multicenter fMRI Quality Assurance Protocol, Journal of Magnetic Resonance Imaging 23:827-839 (2006)