PERFORMANCE AND IN VIVO APPLICATIONS OF SIMULTANEOUS PET/MRI

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Introduction:

The combination of Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) is a promising new hybrid imaging technology. PET/MRI allows combining the high PET sensitivity to track radiotracers in vivo with the tremendous imaging capabilities offered by MRI. Basically two design approaches are feasible for PET7MRI: A PET/CT like approach, which is limited to sequential imaging, where the patient is first scanned in the MRI and then in the PET, or a truly simultaneous approach where PET and MRI images can be obtained isochronously. Our group has developed a small animal PET scanner that can be installed inside a 7 Tesla MRI system and allows for simultaneous data acquisition. The mutual interference of both systems was evaluated. In vivo studies in areas ranging from cardiology to neurology have been performed, which focus on the benefits of simultaneous PET/MR imaging.

Material and Methods:

PET-MR setup: Our group developed an MRI compatible PET-System, consisting of 10 detector blocks, each with a 12x12 LSO scintillation crystal block coupled to a 3x3 avalanche photo diode array. A 35 mm RF coil for MR signal transmission and reception is installed inside the PET insert which is placed in a 7 Tesla small animal MRI system. The combined PET/MRI field of view is 19 mm in axial and 35 mm in transaxial direction.

MR compatibility: The performance of the MR system with installed PET insert was evaluated using phantom studies and compared to the configuration without the PET insert installed in the MRI. The signal to noise ratio (SNR) and image homogeneity for standard MR sequences was measured. The main magnetic field (B_0) and RF field (B_1) was mapped for both configurations, using phase images for the B_0 field and a spin echo/stimulated echo sequence for the B_1 field. Geometrical distortions were assessed for spin echo, gradient echo and EPI sequences by means of image subtraction. EPI imaging stability was evaluated.

In vivo Studies: Three *in vivo* studies were performed to focus on simultaneous PET/MR imaging:

A tumor bearing BALB/c mouse was i.v. injected with [^{18}F]FLT, a PET tracer for cell proliferation. During the PET acquisition high-resolution anatomical MR images were obtained and Gd-contrast agent uptake was monitored. Post mortem histology of the tumor was performed.

Simultaneous cardiac imaging was performed by PET/MR in a BALB/c mouse after [18F]FDG tracer uptake. Both imaging modalities were fed with the same trigger signal, to yield images of the beating heart in PET and MR. Finally, a PET/MR study was conducted in a VM/Dk mouse with a brain tumor. A Gd-MR-contrast agent and ^{15}O-Water were simultaneously injected and the signal time course monitored with PET and MR.

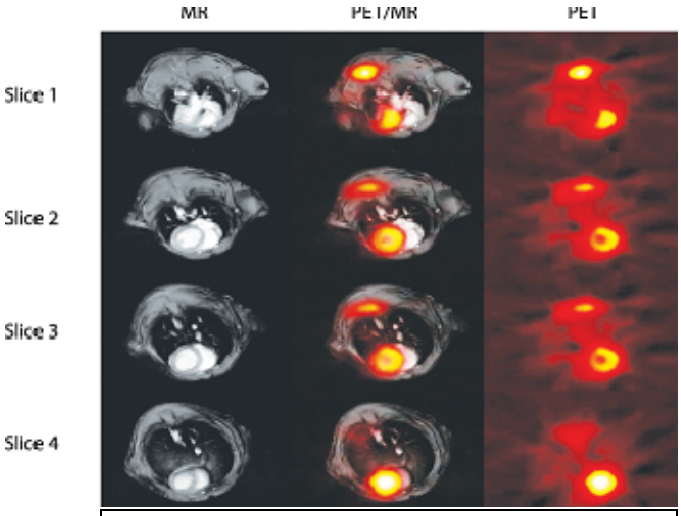

Figure 1: Simultaneously acquired MR and [^{18}F]FDG-PET images of a mouse heart for four different transversal slices.

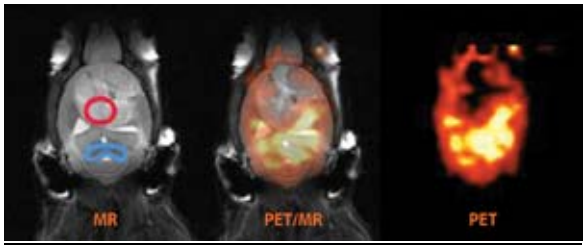

Figure 2: ^{15}O-Water-PET and Gd-MR contrast agent study of a brain tumor bearing mouse (above). The signal-time-curves obtained isochronously with PET-MR are shown on the right. Curves for the tumor (red, orange) and control area (blue) are depicted.

Results and Discussion:

MR compatibility: A decrease of the MR SNR of approximately 8% was seen when the PET insert was installed compared to measurements without the PET insert. Qualitatively, the main magnetic field and the RF field are unimpaired by the PET system. Geometrical distortions are on the order of one pixel size in the respective matrix resolution of the sequence. EPI imaging stability shows a higher signal drift with the PET insert. Some of the effects observed can be attributed to temperature shifts imposed by the PET system.

In vivo Studies: MR and PET images of the tumor are in good agreement with histology. Anesthesia time is significantly reduced by the isochronous acquisition. Simultaneously obtained cardiac images allow assessment of glucose metabolism in the heart via the PET images and anatomical information by the MR data (Fig. 1); this can be used for a more detailed diagnosis and improved PET quantification. The isochronous MR contrast agent and ^{15}O-Water study showed similarities in the obtained signal time course (Fig. 2).

Conclusions:

Simultaneous PET/MRI is a powerful tool especially in the field of multi-functional imaging. It is possible to study two functional processes at the same time with different modalities. This can be used for cross correlation studies, where the same parameters are investigated e.g. perfusion with PET and MRI or for studies focusing e.g. on the BOLD effect, diffusion or spectroscopy with MR and tracer kinetics or perfusion with PET.