An MR-PET phantom for studies of the male pelvis

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Target audience: Researchers interested in combined MR-PET studies.

Introduction: For quality control, attenuation correction, and sequence testing at hybrid MR-PET scanners a specific phantom is needed since both modalities employ completely different physical effects. We considered a phantom of the male pelvis in view of planned studies at our MR-PET system and recent promising results using ^{68}Ga-labelled prostate specific membrane antigen (PSMA) ligands for diagnostics of prostate carcinoma[5]. Reflecting on the possible issues of such a phantom it must enable simultaneous MR and PET imaging as well as MR spectroscopic measurements with ^{1}H and X-nuclei. Our purpose was to develop and test a prototype of such an MR-PET pelvis phantom.

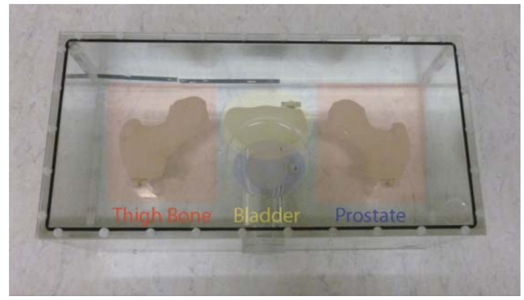

Figure 1: Phantom setup. Components that mimic left and right thigh bone (red), bladder (yellow), and prostate (blue) are fixed inside a water-filled glass box. An endorectal coil can be mounted under the prostate

Methods: All experiments were performed on a commercial MR-PET system with B_0 = 3 T (Biograph™; Siemens, Erlangen, Germany). To obtain the contours of thigh bones and bladder MR images were obtained from the pelvis of a healthy volunteer and segmented using in-house software (MITK-Diffusion[1]). The prostate-like component, designed using CAD[2], consists of 8 spherical cells (volumes: 0.6 to 2.6 ml) within a larger sphere (diameter: 42 mm). All structures were made by 3D printing technique[3] and fixed inside an 11.5-l acrylic glass box. They are hollow and can be filled with different materials or model solutions. Individually designed mounting systems enable easy access and handling of each component. A cylindrical insert allows to attach an endorectal coil. For PET measurements ^{68}Ga obtained from a ^{68}Ga-generator[4] in solutions with different concentrations was added to the contents of the glass box, "bladder", and the 1.2-ml sphere within the "prostate".

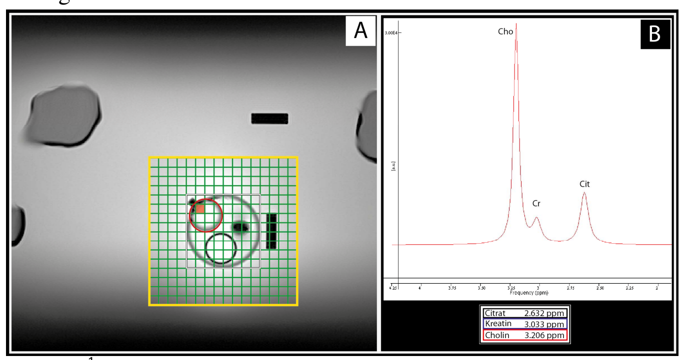

Figure 2: ^{1}H MR spectroscopic imaging (2D-PRESS) of the MR-PET phantom at 3 T. (A) Field-of-view of SI across the "prostate" (grey circle) filled with a model solution of choline (100mM), creatine (50mM), and citrate (200mM). Black bars: Fixation of phantom components. (B) ^{1}H MR spectrum from voxel (red) inside the "prostate" with resolved resonances.

Results: 3D printing was successfully used to model the components of the phantom. Design and sizes are equivalent to a male pelvis region (Fig. 1). Standard attenuation map reconstruction, implemented on the scanner by the manufacturer, was employed. The glass box was filled with demineralized water and 0.5 g/l NaCl to achieve an appropriate background for the attenuation map. A specific problem was the material that mimics bone tissue both in MRI and in PET. To obtain an approximate attenuation map reconstruction for the thigh bone, vegetable oil was used as bone surrogate (Fig. 3, A). Moreover, a mixture of vaseline and K_2HPO_4 yielded promising results both in MR and CT measurements. ^{1}H MR spectroscopic imaging (SI) of the prostate phantom with an endorectal coil could resolve resonances of creatine, choline and citrate in the model solutions (Fig. 2, B). Images of each insert were obtained and SUV evaluations yielded values for the different regions similar to those, which were measured in patients[5] (figure 3, B).

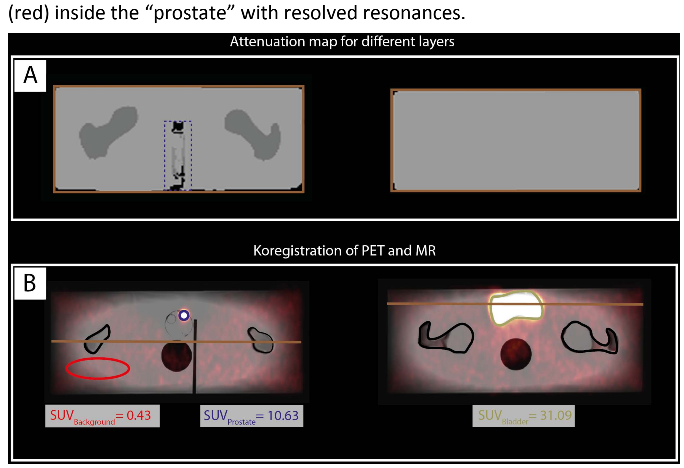

Figure 3: (A) Attenuation-map reconstruction (coronal slices for "thigh bones", right, and "bladder", left). (B) Overlays of transversal MR-PET scans. "Thigh bones" were correctly registered as fat signal (dark grey). As required, "bladder" is not distinguished from background signal. The air-filled endorectal coil is marked (A, blue). ^{68}Ga solution was added to the content of "bladder" (yellow), "prostate" (blue) and glass box (red). Measured SUV values are indicated.

Discussion: Phantom design and handling enabled easy access and quick changes of the different phantom inserts. Simultaneous PET acquisitions, MRI, and MR spectroscopy measurements could be demonstrated with the setup. The first successful application of our phantom concerned the analysis of image artifacts.

References:

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