Systematic Evaluation of Phantom Fluids for Simultaneous PET/MR Hybrid Imaging
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Introduction: With the recent advent of PET/MR hybrid systems the need for combined and simultaneous PET and MR phantom measurements arises. Phantom fluids that are used in MRI are not necessarily applicable in PET, and vice versa. Water, for instance, which is used in PET, as it mixes well with the radiotracer fluorodeoxyglucose (FDG), can result in strong B₁-excitation artifacts in MRI. Especially when imaging large-sized phantoms at high field strength. Hereby, the relative permittivity εr of the phantom fluid is crucial [1, 2]. Low εr, as in oil, is preferable in MRI. However, oil is not applicable for PET imaging, as it doesn’t dissolve FDG. In this study different fluids were systematically evaluated in regard to their usability for phantom measurements in simultaneous PET/MR hybrid imaging.

Materials and Methods: Different fluids were evaluated according to the criteria: relative permittivity, polarity (to specify whether it will mix with the polar substance FDG) and compatibility with plexiglas, used as phantom material. The following fluids, with corresponding εr, shown in Tab. 1, were selected: monoethylene glycol, triethylene glycol and an emulsion of 75% oil and 25% water. Pure oil (for MR) and water (for PET) served as reference. A PET body-mimicking emission phantom (L981602 according to CEC Project (PTW, Freiburg, Germany) with a diameter of 30 cm and a volume of 10 liters was used in this study. All MR measurements were performed on a PET/MR whole-body hybrid scanner (Biograph mMR, SIEMENS AG, Erlangen, Germany) utilizing standard MR protocols. Additional PET measurements of small samples (100 ml) of pure fluids and emulsions of varying oil-water-composition were performed on a PET/CT system (Biograph mCT, 40-slice CT, SIEMENS AG, Erlangen, Germany), with 3.5 MBq of FDG, scan duration of 2 min per bed position starting 30 min p.i.

Results: Monoethylene and triethylene glycol dissolved FDG uniformly in the samples (Fig. 1 A). Based on the selected emulsifier-concentration, the most stable emulsions were achieved with a fraction of 20-25% of water. Already this rather small fraction dissolved FDG within the whole sample homogeneously (Fig. 1 A). Triethylene glycol and the emulsion were additionally evaluated in the PTW phantom (Fig. 1 B, C). Fig. 2 provides a matrix of phantom fluids and measured MRI sequences. The strong B₁-arrays visible in the selected RF-intensive sequences in the phantom filled with water only, can be greatly improved by the chosen fluids, thereby enabling MR phantom imaging not solely limited to non-RF-intensive sequences. The color-maps in Fig. 3 show the distribution of the B₁-field after a defined 90°-excitation and allow for evaluation of its resulting homogeneity. The deviation along the vertical center line is plotted on the related graphs on the right. This demonstrates, that monoethylene and triethylene glycol still remain with residual minor central brightening effects (max. flip angle increase in phantom center of 15° and 9° respectively), while the emulsion provides a more homogeneous flip angle distribution, almost comparable to pure oil.

Discussion: The different substances are rated according to miscibility with FDG, homogeneity of RF-excitation and usability in a phantom experiment (practicability, availability, stability) in Tab. 2. The emulsion was superior in regard to homogeneity of RF-excitation in MRI, however its’ preparation is time-consuming and resulting air bubbles within the emulsion can be seen in both MR (Fig. 2) and PET images (Fig. 1 B). Compared to water, both triethylene and monoethylene glycol improve MR homogeneity notably, but do not eliminate central brightening effects completely in this standard phantom. Between these two, triethylene glycol remains the better alternative due to its’ lower relative permittivity thus providing good B₁-homogeneity.

Conclusion: This study provides a first approach of phantom fluid selection for the given quality standard phantom, and phantoms of comparable size, at 3 Tesla. In comparison to dedicated phantom fluids for either MRI or PET, triethylene glycol poses the best compromise within this study and represents a viable alternative fluid to enable simultaneous PET and MR phantom measurements.