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Unified Proton and Fluorine Imaging of Small and Low Spin Density Samples at a Human Whole-Body 7 T MRI

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Synopsis

In order to provide a system, which allows imaging of ^{19}F MR contrast agents, an in-house-built $^{19}F/^{1}H$ transmit/receive system for 7 T was successfully tested in a human whole-body 7 T MRI system. This system enables the measurement of concentrations of 1.85 mM. For this approach we used a ^{19}F tuned coil which provided still enough signal gain at the proton frequency to allow ^{1}H imaging for comparison. This showed the possibility of using ^{19}F as contrast agents with a quite simple coil design in comparison to other dual tuned approaches.

Introduction

The number of fluorinated substrates used as pharmaceutical drugs has increased considerably during the last years[1]. For medical chemistry and therapy, fluorinated substrates are of high interest, because of the very low natural abundance of fluorine in living organisms leading to background-free ^{19}F images. Furthermore, the high MR sensitivity predestines fluorine for ^{19}F MRS and MRI examinations as a part of contrast agents, e.g. for metabolism studies of pharmaceuticals by using MR techniques[2,3]. However, to date, studies of ^{19}F MRI at 7 T are rare due to the lack of existing coils[4]. Therefore, we have developed and successfully tested in-house-built $^{19}F/^{1}H$ transmit/receive system for 7 T imaging in a proof of principle study. In order to use such a system for detection of contrast agents it is important to be able to detect small volumes as well as small concentrations of the investigated substrates. To exploit the potential for fast imaging, for short TE-substrates containing low concentrations of ^{19}F such as solid TEFLON cases, and for optimizing SNR ultra-short TE sequences were adapted to ^{19}F imaging.

Methods

Measurements were performed with a human whole-body 7 T MRI system (Siemens, Erlangen, Germany). The transmit/receive coil and the casing were designed and build in-house (Fig. 1). The 4 array-elements of the coil were capacitively decoupled and matched to 279.5 MHz, which is the Larmor frequency of ^{19}F at 7 T. The coil elements and the transmit-box were constructed to optimize the ^{19}F-signal at a still sufficiently high gain of the ^{1}H-signal for imaging and shimming. The volume coil had an inner diameter of 6.7 cm. The study used different phantoms: (i) a pure 2,2,2-trifluoroethanol (TFE, $C_2H_3F_3O$) bottle phantom of 4 cm diameter and (ii) 15 ml falcon tubes with different concentrations of TFE dissolved in H_2O (distilled water) between 926.9 mM and 1.85 mM (Fig. 2). For comparison between the obtained ^{1}H to ^{19}F imaging two different sequences were used: UTE (Ultrashort Time of Echo) and FLASH (Fast Low Angle Shot) sequences for imaging (for sequence parameters see figure captions). Both standard ^{1}H sequences were adapted for ^{19}F.

Results and discussion

The sensitivity of the coil-transmit-box unit provided sufficiently high signal intensities both at ^{19}F and ^{1}H which enabled shimming at ^{1}H and imaging at ^{1}H and ^{19}F frequencies even in case of 100% trifluoroethanol phantom. The phantoms showed good SNR and image homogeneity (Fig. 3 and 4) in the ^{1}H and the ^{19}F images. This demonstrates, that imaging for ^{19}F and ^{1}H substrates at a 7 T human scanner is feasible. Except for the volume of the imaged object the spin density and substrate concentration plays an important role when using ^{19}F as a molecular marker substance or contrast agent. In our case we could image concentrations down to 1.85 mM, which is under the sensitivity required for contrast agents[5] (Fig. 4). Thus, the coil architecture and the increased signal at 7 T show, that small amounts of ^{19}F-labeled substances are well detectable potentially enabling the therapeutic monitoring of ^{19}F drugs or using ^{19}F-labeld substances as new contrast agents. The current system can be optimized in decoupling and contacts, which will lead to an even better sensitivity. This means that the diameter of the coil can be extended to a size of a head, which is important for further studies with ^{19}F drugs.

So far, we have only used the ^{1}H signal for shimming; an optimization of the ^{19}F shimming is currently under investigation.

Using the same coil elements for simultaneous ^{19}F and ^{1}H measurements represents an advantage compared to complex dual tuned coils as no additional manipulation is necessary when switching between ^{1}H and ^{19}F. Besides this, the results show that the signal from ^{1}H is still high enough to enable anatomic imaging (Fig. 3) allowing to use both image information, e.g., to depict ^{19}F information on standard anatomy.

This study used trifluoroethanol as a ^{19}F substrate due to its solubility in water. However, other ^{19}F substances can be similarly used. Other non-toxic substances are now under investigation.

Conclusion

The results show that our concept of a phased-array coil with sufficiently broad frequency range allows for ^{1}H and ^{19}F imaging of fluorinated substances at a 7 T whole-body system designed for use of human in-vivo examination even if spin density are low. As 7 T will soon be available for clinical diagnostics this may provide new possibilities to monitor fluorinated drugs used in tumor therapy or treatment of psychiatric diseases.

Acknowledgements

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References

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Figures

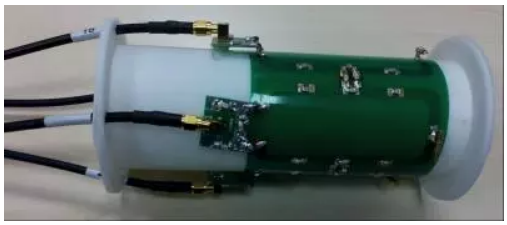

Figure 1: 4-element-phased array coil. The coil was designed and printed in-house.

Figure 2: Phantoms used in the study. Left: Simple bottle phantom (diameter of 4 cm) filled with pure trifluoroethanol ($C_2H_3F_3O$) for testing the coil design; right: 15 ml falcon tubes with different concentrations of trifluoroethanol dissolved in H_2O (distilled water).

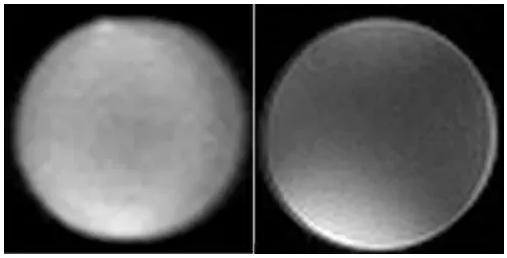

Figure 3: Comparable imaging of the pure trifluoroethanol ($C_2H_3F_3O$) phantom (Fig. 2) with a FLASH sequence. Left: ^{19}F (TE=4.8 ms, TR=4000 ms, 1.5 mm x 1.5 mm x 4 mm); right: 1H (TE=4.8 ms, TR=200 ms, 1.2 mm x 1.2 mm x 4 mm).

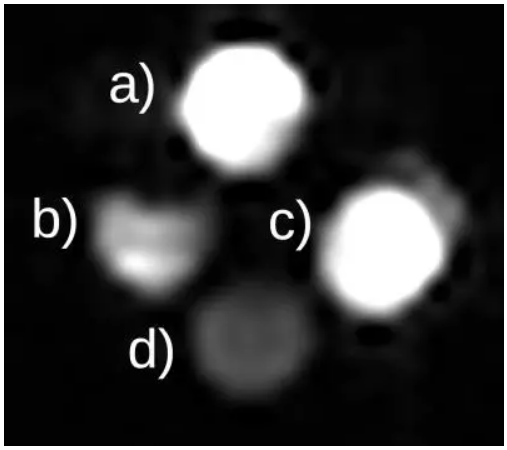

Figure 4: ^{19}F imaging (UTE sequence, TE=8 ms, TR=200 ms, Voxelsize: 2.3 mm x 2.3 mm x 3mm) of 15 ml falcon tubes with different concentrations of trifluoroethanol: a) 926.9 mM, b) 231.7 mM, c) 463.4 mM, and d) 46.3 mM.

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