

Simultaneous ^{19}F and ^1H imaging on a clinical 3T MR scanner

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Introduction

MR imaging based on the ^{19}F nucleus has been identified as an ideal method for the detection and tracking of fluorinated drugs, reporter molecules or targeted nano-particles for molecular imaging in vivo [1]. For localization, a proton image of the morphology is needed in addition, because there is no ^{19}F signal from biological tissue and only exogenous contrast agents are visible. A separately recorded proton image may be inaccurate due to physiological motion between the scans and increases imaging time. In this paper, an MR system is presented that allows the acquisition of ^1H images simultaneously during a ^{19}F imaging sequence using a double-tuned solenoid coil. So far, simultaneous dual-frequency sequences have been used for spectroscopy (proton decoupling) or for Overhauser imaging [2], but not for concurrent acquisition of MR images. In most reported ^{19}F MRI studies, either different RF coils have been applied for the $^{19}\text{F}/^1\text{H}$ acquisitions or the same coil has been retuned [3]. For alternating $^{19}\text{F}/^1\text{H}$ MRI, also double-tuned coils have been used [4,5]. In this study, simultaneous $^{19}\text{F}/^1\text{H}$ imaging was validated in a phantom study on a modified clinical 3T MR scanner.

Methods

The imaging study was performed on a 3T clinical whole-body scanner (Achieva, Philips Medical Systems) with a modified RF spectrometer system. It is based on two digital synthesizers for the waveform generation at the ^{19}F and ^1H resonance frequencies (120 MHz and 128 MHz), which transmit a combined signal over one RF power-amplifier (all modules clinically approved). The double-tuned transmit/receive RF coil with an inner diameter of 7 cm had a homogenous B_1 field at both frequencies extending 4 cm in axial direction. The coil output was connected to two receivers for ^{19}F and ^1H , respectively. The simultaneous image acquisition sequence consists of concurrent RF pulses and data acquisition windows. Timing and magnetic gradients were chosen as for a single ^{19}F 3D gradient-echo acquisition to optimize the image quality for fluorine. Due to the difference in gyro-magnetic ratio γ , the resulting proton image had to be rescaled by 6%. Two nested bottles were filled with pure Perfluoro-Crown-Ether C_9F_{18} (inner volume, single ^{19}F resonance line), and water (outer volume). Imaging parameters were $\text{TR}/\text{TE} = 13.7/6.8$ ms, 128^2 matrix (0.55×0.55 mm² pixel) and 30 slices (2 mm), flip angle 15° , a pixel bandwidth $\text{pBW} = 99$ Hz and 66 seconds scan time. For a high resolution experiment, a 176^2 matrix (0.4×0.4 mm² pixel), 16 slices (0.55 mm), $\text{TR}/\text{TE} = 19.7/9.5$ ms and $\text{pBW} = 70$ Hz was used.

Results and Discussion

Figure 1 shows selected slices out of a 3D simultaneous $^{19}\text{F}/^1\text{H}$ phantom data-set demonstrating the feasibility of the proposed method. The inner bottle with diameter of 5 cm is partly filled with Crown-Ether (Fig. 1a). No spurious signal from the proton frequency is observed. The proton image (Fig. 1b) shows the surrounding water phantom and no signal from the inner bottle. The B_1 homogeneity profile of the solenoid coil is clearly visible. A colored merge (Fig. 1c, ^{19}F green, ^1H blue) shows matching of the fluid shapes after rescaling of the proton image – the glass wall of the inner bottle remains as a gap. With a measured average SNR of 58 for the ^{19}F signal in Fig. 1, it can be estimated that the minimum detectable amount of contrast agent is 70 nmol/voxel in 10 minutes of averaging time (independent of voxel size, $\text{SNR} = 5$). Figure 2 shows a selected slice of simultaneously acquired $^{19}\text{F}/^1\text{H}$ high-resolution 3D data (^{19}F green), where one of the authors held the phantom bottle.

Conclusion

A novel approach to image ^{19}F and ^1H simultaneously has been demonstrated in phantom experiments. This technique will allow the detection and tracking of contrast agents with precise anatomy co-registration in vivo. The measurement set-up shows sufficient sensitivity for molecular imaging purposes as estimated from SNR levels. For future applications, the simultaneously obtained proton signal can be used to follow physiological motion while the fluorine data is recorded.

References

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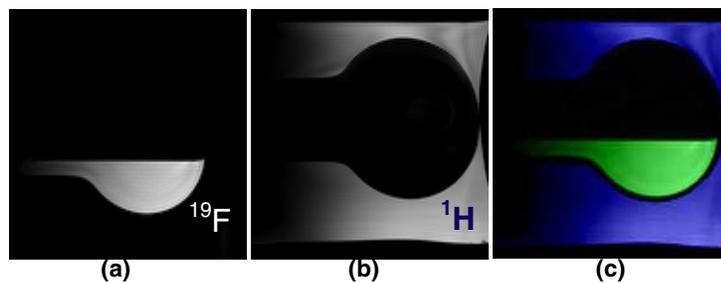


Figure 1: Simultaneously acquired ^{19}F and ^1H images of two nested bottles recorded with a double-tuned solenoid coil on a clinical 3T MR scanner (selected slices of 3D data, $\text{FOV} = 70$ mm). Sequence and gradients were calculated for ^{19}F imaging (a) and a proton image (b) was recorded with concurrent RF pulses and data acquisition. The ^1H image was rescaled by 6% to compensate for gyro-magnetic ratio γ and merged with the ^{19}F image (c).

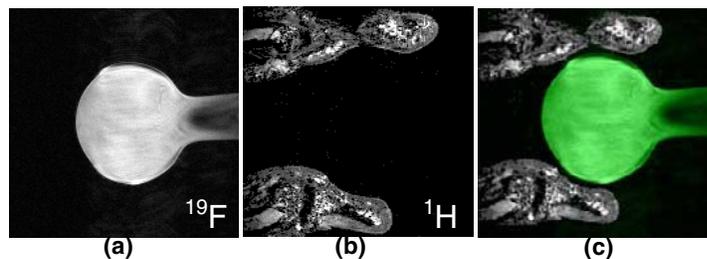


Figure 2: Selected slice out of simultaneously acquired $^{19}\text{F}/^1\text{H}$ high-resolution data ($0.4 \times 0.4 \times 0.55$ mm³). On of the authors held a small bottle filled with Perfluoro-Crown-Ether: ^{19}F image (a) and ^1H image (b), were rescaled and merged (c).