QUANTITATIVE MOLECULAR IMAGING OF FLUORINATED AGENTS: ^{19}F FLIP ANGLE CALIBRATION USING ^{1}H POWER SETTINGS

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Introduction

MR molecular imaging allows for the detection of targeted contrast agents to diagnose disease states and monitor response to therapy, such as angiogenic therapy in peripheral vascular disease [1] or anti-angiogenic therapy in atherosclerosis and cancer [2] with $\alpha_v\beta_3$-targeted nanoparticles. Recently, ^{19}F MR using a ^{19}F/^{1}H dual-tuned RF coil has been utilized to directly image and quantify the fluorinated core of these perfluorocarbon (PFC) nanoparticle (NP) emulsions [3]. However, low concentrations of these fluorinated agents in the body, even in the absence of any physiological background signal, in conjunction with varying RF sensitivity profiles (i.e., B_1-field inhomogeneities) raises obstacles to optimized imaging and accurate quantification [4]. This study presents a strategy to more accurately quantify the sparse ^{19}F signal from PFC NP emulsions through flip angle calibration utilizing the abundant ^{1}H signal. We hypothesize that the RF power settings optimized for ^{1}H can be used to determine the correct RF power settings for the ^{19}F signal acquired with ^{19}F/^{1}H dual-tuned coils.

Methods

All MR data were acquired on a 3.0 T clinical whole-body scanner (Achieva, Philips Healthcare, Best, The Netherlands) with a dual ^{19}F/^{1}H spectrometer system [5]. Two dual-tuned transmit/receive RF coils were used, including a single loop rectangular surface coil (7×12 cm) and a single-turn solenoid coil (11.5 cm diameter, 14 cm length). A perfluoro-15-crown-5-ether (PFCE: $C_{10}F_{20}O_5$) nanoparticle emulsion (2 ml) was prepared as previously published [5], and filled in a glass vial (10-mm height of liquid). To mimic the effects of coil loading *in vivo*, a 250 ml bottle of saline (1.0% NaCl) was also placed within the coil's RF field. Flip angle sweep experiments were performed on the ^{19}F and ^{1}H frequencies (120.1 and 127.7 MHz) independently to determine optimal RF output settings for flip angle calibration. Slice-selective spectroscopic FID sampling was first performed on the ^{19}F signal as a single series, sweeping the flip angle setting from 10° to 210° in 10°-increments with the following parameters: 10.102 kHz offset frequency (center of single PFCE peak), 10 mm slice, 8 kHz excitation BW, TR/TE = 2000/2.6 ms, 4 NSA, scan time 4 min, automated power optimization and shimming preparation phases turned off. Peak power settings were adjusted according to the offset between real and requested 90° pulse, and the sequence was repeated in an iterative fashion until the optimal power setting was achieved. After acquiring a similar data set at this same power setting on the ^{1}H channel for comparison, the process was repeated at the ^{1}H frequency until an optimal power setting was achieved, which was then compared to the ^{19}F setting. This experiment was repeated with the PFCE phantom located at three positions above the surface coil (0 cm, 1 cm and 2 cm), and in three distinct locations in the solenoid coil.

Results and Discussion

The power settings were optimized for ^{19}F and ^{1}H, such that a requested 90° flip angle (FA) yielded a maximum spectral height in the FA sweep. Figure 1 shows a sweep that was optimized for a requested 90° flip angle on the ^{19}F signal [top], and the resultant ^{1}H FA sweep [bottom] using the same power setting (peak power = 122.9 Watts); this yielded a maximum ^{1}H spectral height at 20°, a 70° difference in flip angles. Figure 2 displays the power setting, measured as peak power, required to optimize the 90° requested flip angle for ^{19}F and ^{1}H at three heights above the dual-tuned surface coil. The average ratio of peak ^{19}F power to peak ^{1}H power between the three configurations is 9.15 ± 0.12; thus, for this coil configuration and calibration settings, the ^{19}F channel requires a power setting about nine times that for ^{1}H. Importantly, the ratio between ^{1}H and ^{19}F power settings was independent of position within the B_1 field. The process was repeated for the solenoid coil corroborating that the correction ratio, although greater for this larger coil (i.e., 20:1), was independent of location within the coil. Therefore, once established, the coil-dependent calibration ratio can be used to correct the power settings for ^{19}F imaging based on the ^{1}H signal for all imaging with the coil, regardless of location within the field of view. For sparse fluorine signals such as would be expected in clinical molecular imaging, power settings and calibrations cannot be performed; however, ^{19}F flip angle calibration can be performed based on the rich ^{1}H signal (as in all clinical imaging) by multiplying the ^{1}H-derived power settings by the calibration ratio. Notably, this is a property unique to dual-resonant coils, which cannot be replicated with single-tuned coils or other double-frequency coils with significantly different geometry between ^{19}F and ^{1}H elements.

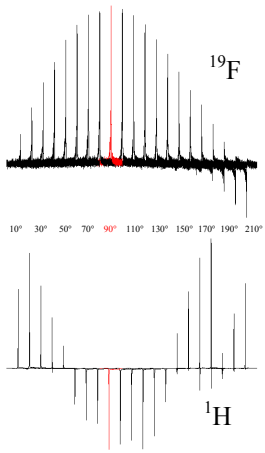

Figure 1. Flip angle sweeps (10°-210°) for ^{19}F signal [top] and ^{1}H signal [bottom] using the same power setting (peak power = 122.9 W) with a ^{19}F/^{1}H dual-tuned solenoid coil indicating correct power settings for ^{19}F, but too high for ^{1}H.

Conclusion

Vital for clinical translation of ^{19}F imaging, the ^{1}H signal can be used to determine the correct power settings for the ^{19}F signal in clinical imaging of perfluorocarbon nanoparticle emulsions acquired with ^{19}F/^{1}H dual-tuned coils using a coil-specific, but spatially-independent calibration value. This technique will allow for power optimization of the abundant ^{1}H signal *in vivo* to be used to determine appropriate power settings for the sparse ^{19}F signal, as is the case in targeted PFC nanoparticle studies, which will ultimately lead to more accurate quantitative measures of these epitopes in patients.

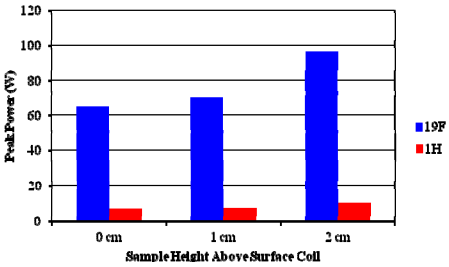

Figure 2. Power settings (peak power, W) needed to optimize 90° flip angle for ^{19}F and ^{1}H signals from sample at 0 cm, 1 cm, and 2 cm above surface coil.

References

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