^{19}F-lanthanide complexes: T_1 - and T_2 - dependent signal gain using gradient echoes

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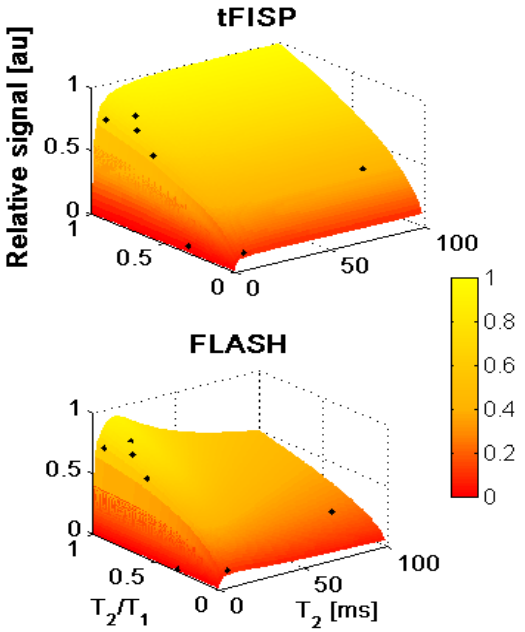
Introduction: ^{19}F-labelled compounds have unique benefits for biological applications. Despite their potential, sensitivity in terms of the available signal-to-noise-ratio (SNR) in MR images is at stake [1]. A significant gain in SNR can be achieved in gradient echo (GE) FLASH images by lanthanide-complexes that shorten the ^{19}F T_1 and T_2 relaxation times [2]. Other groups have shown how ultra-short TE MRI or RARE combined with compressed sensing techniques can be used to boost the ^{19}F signal [3, 4]. GE imaging includes the longitudinal magnetization component only, while the balanced steady state free precession (bSSFP, tFISP) also includes the transverse magnetization component. We explored how these two types of gradient echo techniques perform for compounds with different ^{19}F T_1 and T_2 relaxation times.

Methods: Calculations of the MRI signal for compounds with T_2 between 0.1-400ms and T_2/T_1 ratios of 0.05-1 were performed. For each compound and MRI sequence, the optimal parameter setting that yields the highest signal was selected. Optimal parameters were found as follows: for each bandwidth, field-of-view (FOV) and matrix size, the minimum echo time $\boldsymbol{TE_{min}}$, and repetition times were selected, dependent on the duration of the encoding and spoiler gradients. Finally the optimal flip angle was determined based on the compound and the sequence. A 7T (Bruker BioSpec 70/30, BGA-9S gradient insert, dual 1H/19F single loop surface coil) scanner and a fixed voxel size (1x1x5mm) were used for in vitro measurements. The following 19F lanthanide complexes were measured: LnF1 [2] (Ln= Ho, Dy, Gd) and GdF2 (uncleaved and cleaved by β-galactosidase) [5].

Results and Discussion: For tFISP the signal maximum occurs at higher bandwidths than for FLASH. Therefore shorter TE times can be used with tFISP, which increases SNR. The signal gain depends on the compound and on the duration of the encoding/spoiling gradients. Three ranges can be identified. For compounds with short T_1 < ca 3ms and long T_2 > ca 15ms, the tFISP signal is always greater while for compounds with intermediate T_2 the FLASH signal can be greater if the duration of the encoding/spoiling gradients are sufficiently short. The SNR observed at 7T for the different compounds were in agreement with the signal calculations. For HoF1 (T_2/T_1=9.3/11.3ms) the SNR in vitro for a 5min measurement is similar with FLASH and tFISP: SNR=0.8/nmole, and corresponds to 3.5 for a 4-looped RFcoil, in agreement with [2]. None of the compounds were 'ideal' in the sense that they did not have the ^{19}F T_1 and T_2 times that yields the highest possible signal. With the current approach, ^{19}F compounds should have T_2 times above ca 40ms and a T_2/T_1 ratio of 1 to reach at least 99% of the maximum signal.



References:

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