Assessment of SNR and detection sensitivity of F-uTSI

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Introduction

F-uTSI (Fluorine ultra-fast Turbo Spectroscopic Imaging) is a multi-echo based spectroscopic imaging method (1). The technique is developed for imaging of ^{19}F containing contrast agents that are used in Molecular Imaging applications (2) Most perfluorocarbon materials that are used for Molecular Imaging purposes have multiple resonance lines with a large chemical shift dispersion, causing substantial chemical shift artifact. This problem is also known to have a negative effect on SNR, and therefore, the sensitivity of the contrast agents (3). F-uTSI generates a 2D projection of the imaged objects that is free of any chemical shift artifact and that allows integration of the signal intensity of the different resonances. In this work, results of preliminary SNR efficiency and sensitivity assessment studies of 2D - F-uTSI are presented. Two different perfluorocarbon compounds were used in the experiments; perfluoroctyl bromide (PFOB) and perfluoro-crown ether (PFCE), of which the former is known to have a broad spectrum containing at least five measurable resonance lines, while the latter has only one peak due to its symmetric and cyclic structure.

Materials and Methods

Phantoms filled with PFOB and PFCE were imaged separately using two different k-space sampling schemes for F-uTSI; cartesian and *pseudo*-radial (1). All MR data were acquired on a 3.0 T Philips Achieva system (Philips Medical Systems, Best, The Netherlands) equipped with a home-built coil capable of simultaneous transmitting and receiving at the ^{1}H and ^{19}F frequencies (4). Data were sampled on a 48x48 grid. The signal was excited with a block shaped hard pulse. The offset frequency of the pulse corresponded to either the resonance line of PFCE or the most intense peak in the PFOB spectrum. Spectral bandwidth was 32 kHz and 64 data points were sampled. The reconstruction grid for all acquisitions was chosen to be identical to the k-space size of the acquired data. Spectroscopic images were reconstructed by integrating the spectral signal over a bandwidth of about 3 kHz around the offset value, implying that only one resonance line of PFOB was used. To be able to minimize disturbance and modification of the signal, all temporal and spatial filters, including zero-filling, were turned off. The minimum amount of material per voxel required for detection was determined by imaging the phantoms with varying field of view (FOV). For each experiment the timing factors of the sequence were set to values which would allow sufficient spectral resolution and avoid T_2 weighting artifacts (i.e. echo time: 4.0 ms and echo spacing: 4.2 ms). However, to observe the effect of T_1 relaxation, the measurements were repeated using different TR values varying from the shortest possible TR (110 ms) to a value ensuring sufficient T_1 relaxation (1500 ms). For comparison, the phantoms were imaged using single slice 2D gradient echo and 2D turbo spin echo sequences. The slice thickness was chosen to be large in order to mimic the projection type imaging of 2D F-uTSI. The number of sample averages (NSA) in these experiments was adjusted to achieve scan times identical to those in the F-uTSI measurements. The timing parameters of the sequences as well as excitation and pixel bandwidth were adjusted properly to optimize SNR and select one resonance line only, in order to avoid chemical shift artifacts (Figure 1). The noise was determined using the real and imaginary components of the images. In these, the standard deviation of pixel intensities over a statistically large enough region containing neither signal nor artifacts was measured separately. Consequently, the magnitude of complex standard deviation was calculated for each measurement. The base noise was determined by applying linear regression to the curve describing the relationship between voxel volume and complex noise. The SNR of the measurements were then calculated by taking the ratio of the mean signal obtained from the object and the noise.

Results and Discussions

The detection limits found in F-uTSI experiments were similar to those found for the 2D Gradient and Spin Echo techniques. Figure 2 shows curves describing the dependency of SNR on amount of ^{19}F atoms per voxel for PFOB imaged with cartesian using two different scan times. Based on these, it is found that a practical detection level (SNR = 5) can be achieved with 1.18 μmole PFOB per voxel for a scan time of 40 s(TR: 405ms), while 2D Gradient Echo (NSA = 120) and 2D Spin Echo measurements (NSA = 94) predict this to be 0.68 and 1.10 μmole per voxel, in respective order. When scan times are extrapolated to clinically applicable durations (i.e., 10 min), the detection limit of F-uTSI reduces to 300 nmol/voxel for TR: 405 ms and 220 nmol/voxel for TR: 1500 ms, which, again, are comparable to those of 2D Gradient Echo (180 nmol/voxel) and 2D Spin Echo techniques (284 nmol/voxel). As mentioned above, these results were obtained using only one peak of the PFOB spectrum. Since F-uTSI can, in principle, acquire larger spectral bandwidths without generating imaging artifacts, SNR of the method can be improved further by exciting the molecular spectrum more efficiently and integrating the acquired signal over the whole spectral range. For instance, incorporating a second adequately excited resonance line could yield a two-fold improvement in SNR, making F-uTSI more sensitive than other techniques.

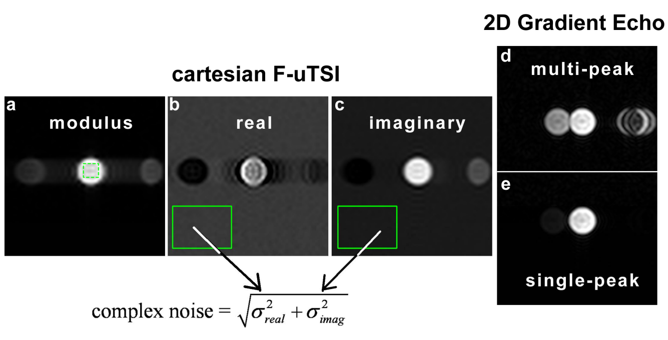

Figure 1 Unfiltered cartesian F-uTSI image (a-c) in comparison with 2D Gradient Echo image (d-e) of a PFOB phantom (FOV:30 mm). The broad-band Gradient echo image (d) illustrates the chemical shift artifact, which can be avoided by choosing a narrower bandwidth (e). The complex noise was determined by evaluating the standard deviation of the image and artifact free regions of the complex images (b, c).

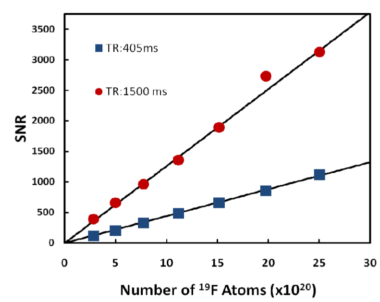

Figure 2 SNR curves obtained with 48x48 Cartesian F-uTSI on PFOB with two different TR values (405ms and 1500 ms).

References

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