

In-vivo ultra-fast Spectroscopic Imaging of ^{19}F containing contrast agents

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Imaging of fluorine-19 containing contrast agents has received increased interest over the last years^{1,2}. Main advantage of ^{19}F is that it does not occur naturally in the human body; therefore, any detected ^{19}F signal has an intrinsic high specificity. The sensitivity of ^{19}F is comparable to that of ^1H , which allows for the detection of ^{19}F compounds in the micro molar range³. However, one of the major drawbacks of ^{19}F compounds is the large chemical shift dispersion of the resonances, as, for example, in perfluoro-octyl bromide (PFOB). If imaged by a gradient or spin echo technique, the resulting images will display a large chemical shift artifact in the read-out direction, as well as in the slice selection direction. To overcome these drawbacks we developed a spectroscopic imaging method, called F-uTSI (Fluorine ultra-fast Turbo Spectroscopic Imaging)^{3,4}. The additional advantage of spectroscopic imaging sequences is that various ^{19}F compounds can be distinguished based on differences in chemical shift of the resonance lines. In short, the F-uTSI method is based on acquiring long spin-echo trains, e.g. 32 echoes can be acquired for each excitation pulse, each corresponding to one k-space value. In this way, a full 64×64 matrix with 1 NSA can be sampled in less than a minutes. For the F-uTSI method we optimized the k-space sampling schemes. Optimal results in the in-vivo studies were obtained with a scheme which we have dubbed 'pseudo-radial' (fig. 1).

Methods.

In-vivo MR data were recorded on a clinical 3T scanner (Achieva Dual-Quasar, Philips Healthcare, Best, The Netherlands). All in-vivo experiments were conducted on black mice (C57BL/6) and were approved by the animal experimental committee of the Maastricht University. Experiments were performed in accordance with the rules and regulations as stipulated in Dutch law. For anesthesia, an intra-peritoneal (IP) injection of KMA mix (Ketamine 75 mg/kg; Medetomidine 1.0 mg/kg; Atropine 0.04 mg/kg) was used. During scanning the anesthesia was maintained by continuous IP infusion of the KMA mix. The body temperature of the animal was supported by a heated animal bed. The contrast agents were introduced into the colon via the rectum. The contrast agent is a 26% (w/w) emulsion of perfluoro-octyl bromide. The animals were sacrificed directly after MR scanning. The animals were imaged in a dedicated double-tuned $^1\text{H}/^{19}\text{F}$ coil. The anatomical ^1H images were recorded with a gradient echo sequence; in-plane resolution $0.2 \times 0.2 \text{ mm}^2$ and 2 mm slice thickness; TR/TE = 415/4.6 ms; scan-time, 13 minutes. The ^{19}F data were collected with the F-uTSI technique. A 64×64 projection image was acquired with an in-plane voxel size of $2.5 \times 2.5 \text{ mm}^2$; 128 echo trains of 32 echoes were acquired. The k-values of the echo-train are sampled according to the 'pseudo-radial' scheme (fig 1). The TR was 378 ms and both the TE and ES were 5 ms; NSA 8, scan time 6:45 min. The offset frequency was set on the CF_2 resonances (see fig 2). The ^{19}F projection images were obtained by integrating the signal intensity of these resonances.

Results and discussion

The present implementation of the F-uTSI sequence yields ^{19}F projection images. Therefore, the overlay of the ^{19}F projection image of the CF_2 resonances is shown on two anatomical proton images of the bowel region (fig. 2). Each voxel still contains the full spectrum and despite the short acquisition window, the resonances of PFOB can still be resolved, e.g. from left to right BrCF_2 , CF_3 and the remaining CF_2 groups. In phantom studies it was shown that this resolution is sufficient to distinguish PFOB from other compounds, such as perfluoro-crown-ether (15-crown-5). On the same animal the ^{19}F signal was also imaged with a gradient-echo sequence (data not shown). The sensitivity of the F-uTSI data was similar to that of the gradient-echo data. The added advantage of the spectroscopic imaging data is that they are free of chemical shift artifact and different fluorine compounds can be distinguished easily. The disadvantage of the projection images can be overcome by either 3D phase encoding or by acquiring projection images in multiple directions in order to reconstruct a 3D view.

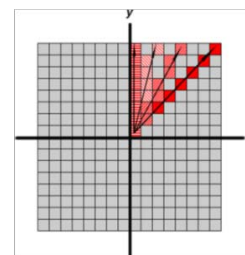


Fig. 1. 'Pseudo radial' k-space sampling. Echo-trains are acquired along radial trajectories, however, the actual k-values are projected onto the Cartesian grid.

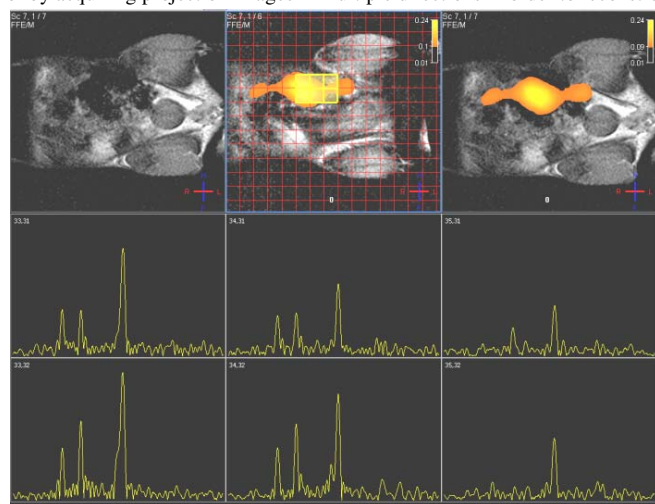


Fig. 2. Projection of the ^{19}F F-uTSI data onto the anatomical images, Note the excellent spectral resolution of the ^{19}F data despite the short acquisition window.

References

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