

# $^{19}\text{F}/^1\text{H}$ Simultaneous 3D Radial Imaging of Atherosclerotic Rabbits Using Self-Navigated Respiratory Motion Compensation

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## Introduction

MR molecular imaging of low doses of tracer material often requires long scan times and makes motion compensation strategies desirable. 3D radial imaging with golden section profile interleaving allows auto-navigated motion compensation [1,2]. Here, it is applied to simultaneous  $^{19}\text{F}/^1\text{H}$  imaging of the aorta of atherosclerotic rabbits after systemic administration of  $^{19}\text{F}$ -based angiogenesis-targeted nanoparticles [3]. Tracking of respiratory motion is performed on the  $^1\text{H}$  data and correction is applied to both the  $^1\text{H}$  and  $^{19}\text{F}$  images to enhance image quality and to provide the possibility of  $^{19}\text{F}$  quantitation of tracer concentrations.

## Methods

Rabbits put on cholesterol diet to develop atherosclerosis [4] were injected intravenously with  $\alpha_v\beta_3$ -targeted nanoparticles (NP) containing high concentrations of lipid-encapsulated perfluorocrownether (PFCE) [3]. Three hours post injection, the MRI exam was performed on the anesthetized and externally respiration rabbits. PFCE exhibits a single line spectrum and is imaged using simultaneous  $^{19}\text{F}/^1\text{H}$  MRI in order to visualize the  $^{19}\text{F}$  image with anatomical co-registration. 3D radial gradient echo imaging was employed for its robustness against sub-sampling and motion [5]. Angular increments (cf. Fig. 1) between readouts were derived from 2D golden section fractions [1], allowing almost isotropic coverage of  $k$ -space over the total scan as well as over arbitrary subsets extracted for dynamic imaging. Thus, the frame rate for dynamic imaging can be chosen retrospectively depending on available SNR and desired temporal resolution. The balance between SNR and spatial resolution can furthermore be influenced by adequate  $k$ -space weighting of radial samples in the gridding process of the 3D radial reconstruction. Experiments were performed on a modified clinical 3.0T whole body scanner (Achieva, Philips Healthcare, The Netherlands) [6] using a dual-tuned

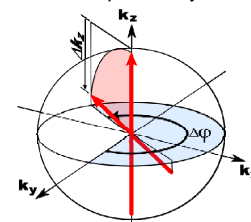


Figure 1: Golden section increments  $\Delta k_z$  and  $\Delta \phi$  between subsequent radial readouts.

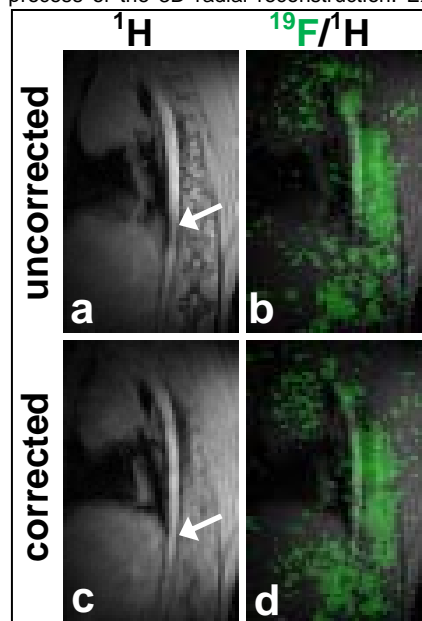


Figure 2: Comparison of uncorrected and 3D motion-corrected  $^1\text{H}$  and  $^{19}\text{F}$  data.  $^1\text{H}$  and green  $^{19}\text{F}$  overlay images extracted from 3D data without correction (a,b), and with rigid-body motion correction (c,d), based upon a frame duration of 1/3 s.

## Conclusion

3D isotropic undersampled radial imaging using golden section profile interleaving allows flexible 3D respiratory motion compensation by self-navigation. Frame rates on the order of 3 Hz are feasible, which is sufficient to resolve rabbit or human respiratory motion. Application to simultaneous  $^{19}\text{F}/^1\text{H}$  imaging has been shown, but the achieved frame rates make the approach useful for compensation of respiratory motion in abdominal or cardiac  $^1\text{H}$  imaging as well.

## References

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(Achieva, Philips Healthcare, The Netherlands) [6] using a dual-tuned  $^{19}\text{F}/^1\text{H}$  T/R rectangular surface coil (7 cm  $\times$  12 cm). For reference, an external respiratory motion sensor was placed on the rabbit's abdomen. In-vivo experiments were performed according to an institutionally approved animal protocol. Typical scan parameters were: FOV = 140 mm, isotropic matrix size  $96^3$ , 138230 radial profiles, TE = 2.1 ms, repetition time TR = 6.1 ms, flip angle  $\alpha_{19\text{F}}/\alpha_{1\text{H}} = 48^\circ/12^\circ$ , total scan duration about 14 minutes. The long acquisition time allowed detection of the  $^{19}\text{F}$ -labeled tracers with reasonable SNR. For motion tracking, the  $k$  space data were retrospectively divided into the desired number of frames. Here 2400 frames were created to achieve a temporal resolution of about 1/3 s. All frames were reconstructed and the  $^1\text{H}$  frames were used for motion registration. For 3D respiratory motion tracking, the cross-correlation between a subvolume of interest with the respective subvolume of a reference frame was calculated. The extracted 3D translational motion information was used to correct the  $^{19}\text{F}$  as well as the  $^1\text{H}$  images.  $B_1$  maps were acquired to allow correction for the coil sensitivity profile.

## Results and Discussion

Figure 2 shows a slice of 3D  $^{19}\text{F}/^1\text{H}$  in-vivo data acquired using the golden section technique. (a,b) show the  $^1\text{H}$  and  $^{19}\text{F}$  images without motion compensation, whereas (c,d) are motion-compensated. Clearly, structures close to the upper edge of the liver appear sharper in the motion compensated  $^1\text{H}$  image. Also, the lower part of the aorta (arrows) is not distorted in the corrected image. The  $^{19}\text{F}$  image shows signal in the aorta, spine, liver, and heart. The effect of motion compensation is not as prominent as in the  $^1\text{H}$  image, mainly due to the lower resolution resulting from a lower weighting of high  $k$  space component to increase SNR. For  $^{19}\text{F}$  quantitation, however, motion compensation is essential. Figure 3 compares the motion information extracted from the  $^1\text{H}$  data with the information obtained from the breathing pad. The self-navigated approach detects respiratory motion in SI (red) and LR direction (blue), whereas in AP direction (green) no relevant motion occurs.

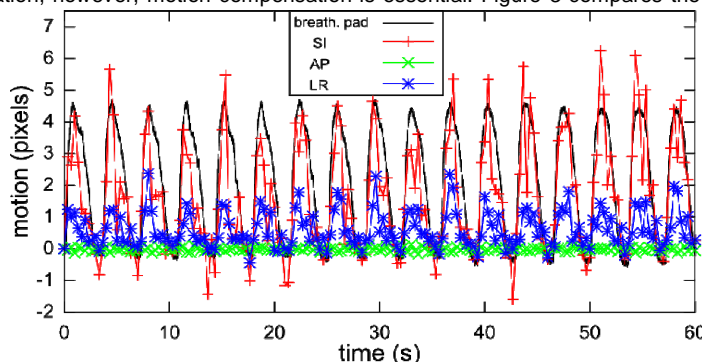


Figure 3: Comparison of a one-minute window of motion extracted from image data (color) with motion information acquired using a breathing pad (black). Red, green, and blue indicate directions SI, AP, and LR, respectively. Temporal resolution was 1/3 s.