Motion Correction for ^{19}F radial MRI based on a simultaneous proton signal

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Introduction

^{19}F-labeled molecular probes or drugs [1] offer a high potential for diagnostic MR imaging [2] with excellent specificity. However, due to low concentrations of externally administered ^{19}F-probes, long averaging times (10 minutes or more) are necessary to measure the distribution in vivo. To avoid blurring or erroneous anatomical location of the fluorine signals caused by physiological motion, efficient detection and correction schemes are required. While ^{19}F-signals are typically too sparse and weak for motion tracking, the proton signal can be used for this purpose, when it is measured at the same time. Sub-sampled radial k-space acquisitions [3,4] are well suited for motion detection, because sub-sampling artifacts are evenly distributed, and the k-space center is acquired for each projection. With the radial imaging sequence presented in this work, averaging of the fluorine signal and proton based motion tracking can be performed without additional scan time. The gradient strength is adjusted for the fluorine frequency, and concurrent RF pulses and acquisition windows are applied on both frequencies. Registration of the time resolved proton image series can be done for translations or for affine transformations, which are subsequently applied to the correction of fluorine projections in k-space.

Methods

The study was performed on a 3T clinical whole-body scanner (Achieva, Philips Medical Systems) with a dual-tuned transmit/receive RF coil (∅ 7cm) and an extended spectrometer system [5]. Images were recorded with a 3D radial gradient-echo sequence (2D radial acquisition + 1D phase encoding), using simultaneous dual-frequency (^{19}F/^{1}H) RF pulses and acquisition windows as well as the following parameters: matrix 176^2, voxel $0.68\times0.68\times3$ mm^3, 19 slices, TR/TE = 7.4/3.1 ms, flip angle $\alpha = 15°$, pixel bandwidth 300 Hz. Each of the 10 averages (4 minutes overall scan time) with full radial sampling (175 projections) were divided in 5 sub-sampled acquisitions with uniformly distributed radial angles, lasting for 5.1 sec. The bottle phantom, containing 7 tubes filled with Perfluoro-Crown-Ether ($C_{10}F_{20}O_5$, single resonance line) enclosed by water, was moved irregularly by about ± 10mm during the entire scan. The sub-sampled proton acquisitions were individually processed by gridding-reconstruction and registered in the spatial domain using the TurboReg algorithm [6]. Motion information can be obtained in 3D, but was restricted to 1D translations in this study. For the time periods of 5.1 sec, the motion was considered to be frozen. Subsequently, the measured translations were rescaled for the difference in gyro-magnetic ratio of 6% between fluorine and proton and applied to the sub-sampled ^{19}F radial acquisitions by linear phase transformation in k-space. All sub-sampled ^{19}F data were then combined to a fully sampled k-space (10 averages). For comparison, the motion registration was also performed directly on the fluorine data, which was possible due to the strong signal of the undiluted fluorine imaging probe.

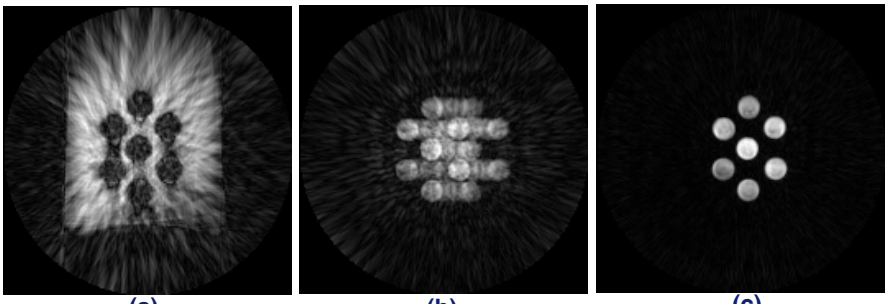

Figure 1: With a simultaneous ^{19}F/^{1}H radial sequence, sub-sampled proton images (a) are obtained with high temporal resolution (5 sec). This offers sufficient information for image registration to measure translations or deformations. Hence, the simultaneously recorded ^{19}F image, which is corrupted by motion (b) can be thoroughly corrected (c).

Results and Discussion

Figure 1 shows an example of simultaneous radial imaging and motion correction of the averaged fluorine image. Despite the sub-sampling artifacts and intra-scan motion effects in the proton images (Fig. 1(a)), sufficient motion information can be obtained by image registration. This is proven by a comparison between motion detection using fluorine and proton data only. As shown in Figure 2, the mean deviation between fluorine or proton image based translation measurement is 0.1 mm/0.2 pixel (maximum 0.3 mm). Reliable motion detection on the proton channel is also demonstrated by the quality of the motion artifact correction on the fluorine channel. While the uncorrected image (Fig. 1(b)) is substantially blurred and shows radial streak artifacts, the corrected image (Fig.1(c)) shows the same quality as an image recorded without motion. As a full 3D volume is acquired in the sub-sampled images, the correction method can be applied to all directions with equal temporal resolution. The presented method is able to recover/correct fluorine signals which are almost invisible in the individual sub-sampled data sets. In case of fast motion, the temporal resolution of the technique can be improved by interpolation between the detected positions or by including a measurement of the phase properties of individual projections [4]. To extend the fluorine radial acquisition to the case of multi-spectral line imaging probes, spectral selective RF excitation can be considered.

Conclusion

This work demonstrates the feasibility of time efficient and precise motion correction for fluorine signals in case of subject motion, enabled by simultaneous fluorine/proton data acquisition. The results are promising for imaging of diagnostic agents in vivo.

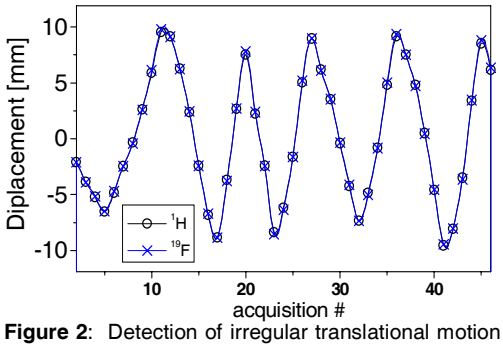

Figure 2: Detection of irregular translational motion on fluorine channel or proton channel (strong fluorine signal) only deviates by 0.1 mm.

References

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