In vivo simultaneous multiple 19F marker tracking using an improved 3D Golden Angle sampling scheme

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Introduction: Dynamic 3D localization of multiple point signal sources using interleaved multiple frequency Cartesian projections has been proposed for tracking small fluorine (19F) labeled capsules administered in humans [1]. Disadvantages of this method are a reduced temporal resolution due to the interleaved acquisition scheme and an SNR bound by the predefined number of projections per Cartesian direction. To overcome these limitations, a 3D Golden Angle (3DGA) imaging sequence [2] has been proposed for the *simultaneous* tracking of multiple markers with the same single resonance frequency [3]. The 3DGA acquisition scheme guarantees a quasi-homogenous coverage of k-space at any time and for any selected reconstruction window. Tracking of 19F markers is performed by peak finding on 3D images reconstructed from undersampled k-space data with reconstruction window size N. A posteriori reconstruction allows for sliding window reconstruction, free choice of N and constrained reconstruction by multiplication of dynamic image data (N small) with 3D images covering a large temporal range. In the present study, the 3DGA tracking method [3] with optimized TR and excitation pulse was applied in vivo for the tracking of three 19F single resonance insoluble capsules administered simultaneously.

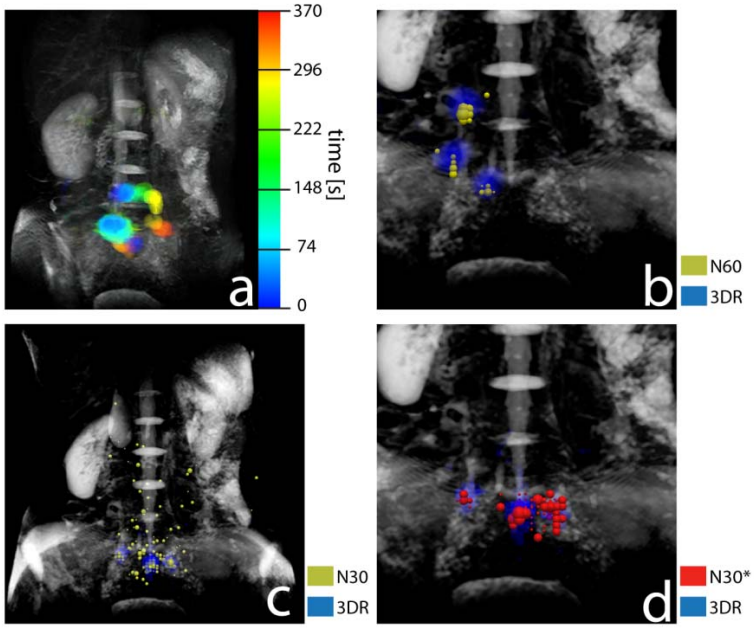

Figure 1 (a) 1H and 19F image overlay of 19F 3D Golden Angle based capsule tracking in vivo. 10 fluorine images with 24s total scan duration were acquired at 37s time steps and reconstructed from 6400 k-space profiles each and are color coded according to their scan start time. **(b)** Capsule tracking with reconstruction window size N = 60 during a 24s scan window (dataset 1). The reconstructed 3D 19F image of the full dataset (N = 6400) is overlaid in blue. **(c)** Exemplary capsule tracking with N = 30 for dataset 2. **(d)** Constrained capsule tracking with N = 30 for dataset 2.

Methods and Materials: ***In vivo data acquisition:*** 3DGA tracking of three capsules [1] was performed in one healthy volunteer on a 3D whole-body Achieva MR system (Philips Healthcare, Best, The Netherlands), using a dual-channel 19F transmit-receive surface coil (PulseTeq Ltd, 20cm diameter). Capsules were filled with 65 µl Perfluoro-15-crown-5-ether (PCE) as liquid 19F marker. Anatomic images were acquired for data coregistration. 3DGA sequence scan parameters were: FOV 32x32x32 cm^3, TR/TE (ms) 3.6/1.8, spatial resolution 4 mm, 3D non-selective excitation, flip angle 38°. 30 datasets, each consisting of 6400 radial profiles (scan time = 24s), were acquired over a 1 hour study period. ***Data processing:*** 3D images were reconstructed using FFT of gridded 19F k-space data. 3D peak finding was performed on this image data for capsule localization. Using differently undersampled data with reconstruction window sizes of N = 30, 60, 90, 120 and 150 radial profiles, 'undersampled fluorine 3D images' were created. These were compared to the fully sampled image (N = 6400) with regard to SNR and computation time. For visualization of the intestinal 3D movement of the 19F capsules, 10 3D images using a reconstruction window size of 6400 were overlaid onto the anatomic reference scan (Fig.1a). To study the effect of local SNR increase by constrained reconstruction, cf. HYPR [4], dynamic image data with a small reconstruction window size (N = 30) were multiplied with fully sampled images (N = 6400) before peak finding. Uniform weights were used for gridding of the fully sampled data to generate a 'diffuse' spatial constraint.

Results: SNR as a function of reconstruction window size is given in the Table. Capsule coordinates generated from N = 60 profiles matched the 19F image data reconstructed from N = 6400 (Fig.1b). In contrast, peak finding with N = 30 was not robust due to the low SNR (Fig.1c). SNR could locally be increased by constrained reconstruction (Fig.1d), allowing for peak finding in the constrained volumes. SNR of reconstructed 3DGA 1D projections ranged between 5 and 40 (Fig.2) and is comparable to the SNR observed for the Cartesian projection method [1]. The variation in SNR may be attributed to the underlying breathing resulting in feet-head motion of the capsules (Fig.2).

N	30	60	90	120	150	6400
Δt [ms]	108	216	324	432	540	23040
SNR	26	37	45	51	57	310
C [s]	666	353	255	183	153	12

Table Different reconstruction window sizes (N) with corresponding temporal resolution (Δt), resulting SNR and computation time (C) applied in one dataset.

Discussion: The proposed 3DGA method allows for 19F imaging of sparse exogenous signal sources in the human abdomen. Temporal resolution and SNR can be freely adjusted for optimized tracking at different object velocities. Constrained reconstruction may be used to further increase SNR at high temporal resolutions beyond 216ms. Long lasting signal voids may result in ambiguities concerning capsule coordinate assignment. Therefore, this method might be most valuable for the tracking of fixed 3D marker geometries, e.g. for catheter tracking.

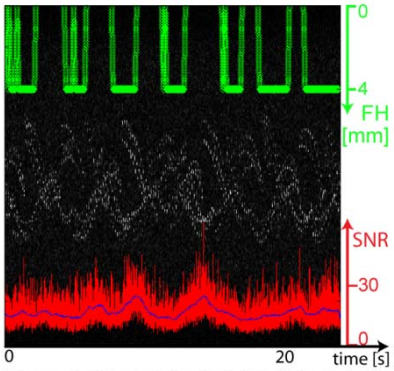

Figure 2 1D reconstructed 3D Golden Angle projections for one exemplary data set. Peak SNR for each projection is given in orange and blue (smoothed). Corresponding feet-head motion of one capsule (FH) is reconstructed using constrained reconstruction with N = 30.

References: [1] Hahn et al. MRM 2011 [2] Chan et al MRM 2009 [3] Hahn et al. ISMRM 2011 [4] Wieben et al. ISMRM 2006