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PRESENTATION TITLE
Optimizing acquisition speed and contrast of respiratory correlated 4D-MRI on the 1.5T Unity MRI-linac

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ABSTRACT
Purpose: Over the last few years various 4D-MRI methods have been developed, but mostly on diagnostic 1.5T or 3T scanners in a research setting. The goal of this work is two-fold: 1) assess the image quality of respiratory-resolved 4D-MRI acquisition strategies with varying contrast on a 1.5T MRI-linac system and 2) optimize acquisition speed for online abdominal motion characterization.

Materials & Methods: A self-navigated golden angle Stack-of-Stars (GA-SoS) 4D-MRI method was implemented on the 1.5T MRI-linac (Elekta Unity, Elekta AB, Stockholm, Sweden) installed at the University Medical Center Utrecht. Two healthy volunteers were scanned with the standard 2x4 coil array. Three different 4D-MRI data sets were acquired with different contrasts: 1) balanced steady-state free-precession (bSSFP) with a mixed T2/T1 contrast, 2) bSSFP with fat suppression, and 3) T1-weighted RF- and gradient-spoiled gradient echo (SPGR) with fat suppression. All acquisitions were matched in terms of resolution (1.5x1.5x4.0mm³), coverage (330x330x152mm³), and readout bandwidth (861 Hz/pixel). The amount of acquired data was also equal in all three acquisitions (1760 radial projections), leading to acquisition times of 4m25s, 5m56s, and 6m55s, for the three acquisitions respectively. Data were reconstructed on a reconstruction server into ten respiratory phases using phase binning with self-navigation extracted from the k-space center. A compressed sensing algorithm with temporal total variation regularization was used to minimize undersampling artefacts, while maintaining temporal fidelity. The regularization factor was set conservatively low to minimize motion underestimation. After reconstruction, DICOM images were generated and exported to the clinical database. To determine the minimal acquisition time for the three acquisitions, data were retrospectively undersampled and reconstructed using the same pipeline with equal regularization. Non-rigid displacement was calculated, using a previously validated optical flow algorithm on all reconstructions. The motion of both kidneys and the pancreas was compared between the fully sampled and undersampled reconstructions.
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**Results:** Figure 1 shows a comparison of the three acquisitions highlighting specific parts of the abdomen in inhale, exhale and mid-position phase for one of the volunteers. While the bSSFP without fat suppression displays residual streaking originating from subcutaneous fat, both fat suppressed acquisitions show virtually no streaking. After performing a DICOM export, these data could all be viewed in our clinical viewing software (Volumetool). Figure 2 shows the pancreatic motion extracted for various undersampling factors in one of the volunteers. Although the undersampled data showed increased streaking artifacts, motion quantification was still feasible when only 18.75% to 37.5% of the data was used, corresponding to acquisition times between 49s - 1m39s, 1m6s - 2m13s, and 1m18s - 2m36s for the three acquisitions.

**Conclusions:** Self-navigated GA-SoS 4D-MRIs with different imaging contrast were successfully acquired on the 1.5T Unity MRI-Linac. Motion characterization on highly undersampled data is feasible, which will significantly reduce the acquisition time in online applications. The reconstructions were performed on a reconstruction server, enabling accessibility of the 4D-MRI data in the clinical database. This facilitates online 4D-MRI prototyping with our Utrecht Treatment Session Manager (UTSM), expediting clinical introduction of this technique.

![Figure 1 Overview of reconstructed images for one subject. For the three contrasts (bSSFP, bSSFP + fat suppression, SPGR + fat suppression) the exhale, inhale, and mid-position volumes are shown.](image1)

![Figure 2 Pancreatic cranio-caudal motion for the different undersampled and fully sampled T1w reconstructions for one of the subjects.](image2)