Experimental Validation of SMS-LORAKS

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PURPOSE: Low-rank matrix modeling of local k-space neighborhoods (LORAKS) is a novel technique for accelerating MRI that uses regularization to impose limited spatial support, smoothly varying image phase, and/or parallel imaging constraints [1,2]. SMS-LORAKS is an extension of this technique to simultaneous multislice imaging (SMS) [3,4]. While traditional SMS techniques require structured data acquisition, SMS-LORAKS offers new flexibilities in the SMS experiment; it supports both calibration-based and calibrationless undersampled k-space sampling schemes, unconventional forms of undersampled partial Fourier acquisition, both traditional RF encoding and novel forms of incoherent RF encoding [5], and can be used with both single channel and multi-channel data without sensitivity maps. However, all previous SMS-LORAKS results were shown using simulated data [3,4]. In this work, we report experimental validation of SMS-LORAKS.

METHODS: ***Experiments*** were performed on a 3T GE scanner using a GRE sequence with TR = 1 s, TE = 8 ms, matrix size = 256x186, and an 8-channel head coil. Fully sampled reference images and 2.5x prospectively undersampled SMS data were acquired as described in Ref [3] using a random calibrationless partial-Fourier k-space sampling pattern. For an example, please see fig. 1. ***RFpulse:*** A 4 ms sinc pulse was modulated to excite two 0.5 cm thick slabs, 6 cm apart. Hadamard and semi-random RF phase encoding schemes were considered. For the semi-random scheme [5], a different phase was added to each slice for each TR and the RF pulse is played as a real pulse plus a constant phase. For certain k-space lines that were acquired twice, we required that the phase differences from each repetition were more than 30 degrees apart to improve the conditioning of the inverse problem. ***Analysis:*** Experimental results were compared against numerical simulations of the ideal SMS experiment based on fully sampled reference images.

RESULTS and DISCUSSION:

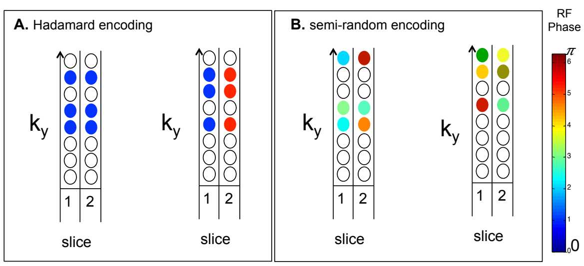

Fig. 1: Cartoon example of calibrationless A) Hadamard encoding and B) semi-random encoding.

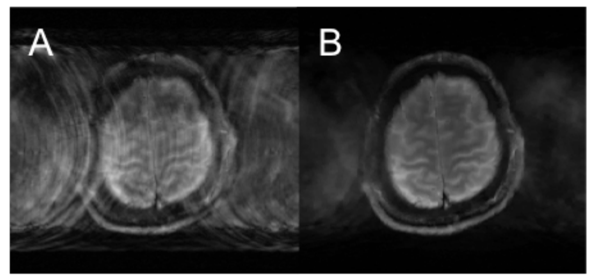

Fig. 2: In-vivo results showing simulated data with A) MNLS and B) Joint TV reconstruction.

Fig. 2 shows simulated undersampled SMS data with Hadamard RF encoding reconstructed using minimum norm least squares (MNLS) and joint total variation (TV) for comparison with SMS-LORAKS. One slice is shown to save space. Fig. 3 shows the results of simulated versus experimental SMS data for Hadamard and semi-random RF encoding. Note similarity between simulated and experimental results. Some small differences could be due to slight subject movement between scans. Please note a thinner right lateral ventricle in the first row images with real data (red arrows), which is also accompanied by a slight change in position of the skull. Comparing the results of figures 2 and 3, we illustrate a key advantage of SMS-LORAKS; we do not know of other methods that work as well to reconstruct data acquired with calibrationless partial-Fourier k-space sampling.

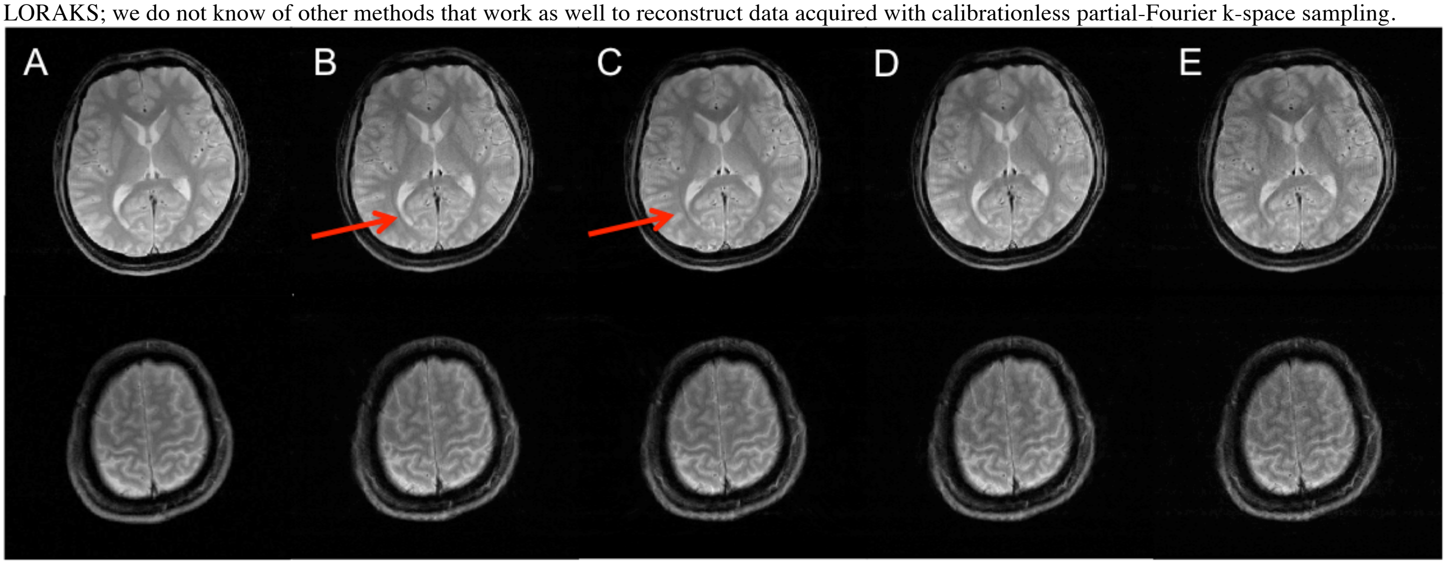

Fig. 3. In-vivo results showing A) reference slices, and SMS-LORAKS reconstruction using B) Hadamard encoding with simulated data, C) Hadamard encoding with real data, D) semi-random encoding with simulated data, and E) semi-random encoding with real data.

CONCLUSION:

In this work we have experimentally validated SMS-LORAKS for the first time by comparing SMS-LORAKS results of simulated vs. real data with Hadamard and semi-random encoding at 2.5x acceleration. We have demonstrated the consistency between simulation and real data results, thus reinforcing the potential for SMS-LORAKS.

REFERENCES:

[1] Haldar, IEEE TMI 33(3):668-81, 2014 [**2**] Haldar MRM 2015 (In Press) **[3]** Kim, ISMRM 2015, p. 3918 [**4**] Kim, ISBI 2015, p. 323-326
[**5**] Haldar IEEE TMI 30(4):893-903, 2011