Minimization of Imaging Artifacts from Profile Ordering of Randomly Selected k_y-k_z Lines for Prospective Compressed-Sensing Acqusition in 3D Segmented SSFP and GRE Imaging

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INTRODUCTION Compressed sensing (CS) reconstruction allows recovery of a compressible image from randomly under sampled frequency data. For Cartesian acquisition in MRI, this means a random under-sampling in k-space [1]. In 2D imaging, only k_y lines are randomly selected for prospective CS acquisition, but in 3D, both k_y-k_z lines can be selected. In addition to selecting random sampling lines, the profile ordering in which these lines are acquired will also impact the imaging contrast and artifacts. Furthermore, different imaging sequences have different sensitivity to this acquisition profile ordering during acquisitions. For SSFP, eddy current artifacts from rapid gradient switching could have significant impact on image quality [2]. In this work, we sought to investigate a radial reordering scheme for randomly selected k_y-k_z lines for segmented, ECG triggered SSFP and GRE acquisitions for coronary MRI. Both phantom and *in vivo* experiments were used to investigate the proposed re-ordering scheme.

MATERIALS AND METHODS Prospective Undersampling: The proposed randomization and profile ordering of k_y-k_z lines consist of two steps. Initially, a subset of the fully-sampled k_y-k_z lines is selected based on the desired undersampling rate (R), while ensuring that the central k_y-k_z region is included. Subsequently, the selected k_y-k_z lines are reordered in a radial fashion prior to the acquisition: The selected points are sorted based on magnitude specified by their (k_y,k_z) location. These selected points are divided into groups, such that the total number of groups is equal to the number of lines in an imaging segment. Then, each group is sorted individually based on the phase specified by the (k_y,k_z) location. For each i^{th} imaging segment, the i^{th} element from each of the sorted groups is acquired sequentially. This ordering scheme reduces the gradient switching by minimizing jumps between subsequently acquired k_y-k_z lines.

In prospective CS k-space sampling for evaluation of various imaging sequences, it is helpful to distinguish between aliasing artifacts due to undersampling vs. other sources of artifacts such as eddy currents and variations of exogenous contrast agents as a function of time. Therefore, we developed the pulse sequence with two options: **1) True Prospective Undersampling***:* the k-space is undersampled with the desired acceleration rate and the scan completes upon acquiring these lines, and **2) Simulated Prospective Undersampling***:* A true prospective undersampling acquisition is performed for a given acceleration rate, followed by the acquisition of the remaining k-space lines to generate a fully-sampled k-space.

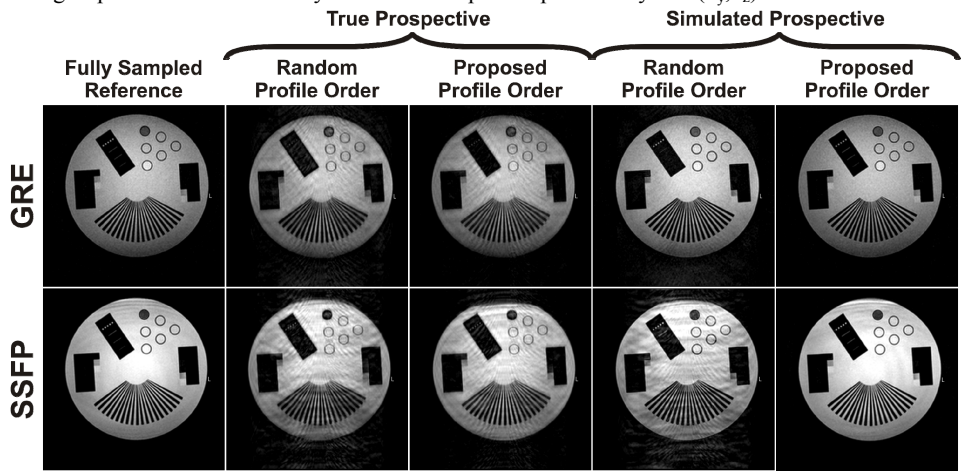

Fig. 1: *Phantom results for GRE and SSFP acquisitions with true and simulated prospective undersampling (R = 2). For each acquisition, the first column represents the random profile ordering while the second column represents the proposed radial profile ordering.*

Image Acquisition & Reconstruction: Images were acquired on a 1.5T Philips Achieva with 5-channel cardiac coil. A phantom study was conducted to evaluate the proposed profile ordering scheme using both 3D GRE (TR/TE/α=5.2/2.5/30°, FOV=256×256×30mm^3, resolution=1.3×1.3×2mm^3) and SSFP (TR/TE/α=3.8/1.9/110°, FOV=256×256×30mm^3, resolution=1.3×1.3×2mm^3) sequences, and with true and simulated prospective undersampling. Subsequently, 4 healthy adult subjects were imaged using both the random and the proposed profile ordering schemes with a 3D segmented SSFP sequence for coronary imaging (TR/TE/α=4.3/2.1/90°, FOV=270×270×30mm^3, resolution=1×1×3mm^3). The acquired data was then transferred to a separate workstation where a CS reconstruction algorithm, based on l_1 minimization [1], is applied to reconstruct the images.

RESULTS AND DISCUSSION Fig. 1 shows the phantom results for the GRE and SSFP acquisitions using true and simulated prospective undersampling with rate 2. Artifacts reduction can be noticed in the images from the proposed profile ordering. Moreover, the images show that the gradient switching artifacts not only appear with the SSFP acquisitions, but also with the GRE ones. Fig 2 shows an example from the *in-vivo* results for right coronary. The CS reconstruction for the true prospective undersampling, (R = 2), with the proposed profile ordering (c) shows less artifacts and better image quality than the fully sampled data but with random profile ordering (b).

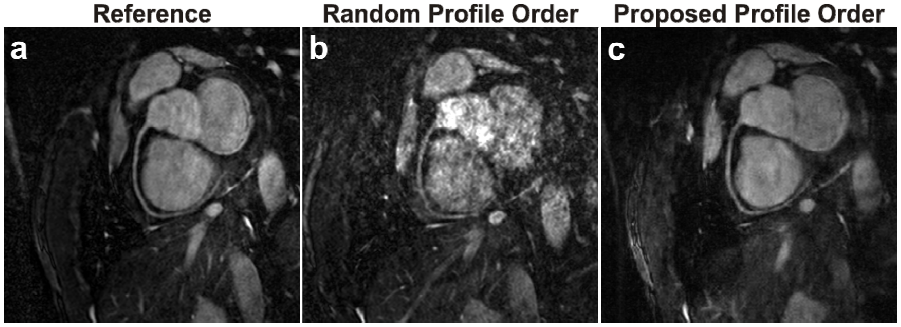

Fig. 2: *In-vivo results for RCA images: a) Reference image, b) Image from simulated prospective undersampling (R=1, i.e. data is fully sampled) with random profile ordering, c) Reconstructed image from true prospective undersampling (R=2) with proposed profile ordering.*

CONCLUSION In a prospective 3D segmented CS acquisition, a radial profile ordering of the randomly selected k_y-k_z lines minimizes the artifacts associated with the gradient switching. These artifacts always appear in the randomly ordered k_y-k_z lines acquisitions.

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