A Self-Calibration Technique for Suppression of Radial Undersampling Artifacts in Parallel Imaging

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Introduction: In undersampled radial acquisitions for accelerated imaging, streak artifacts due to the convolution of an image and the polar point spread function (PSF) may severely degrade the image quality [1, 2]. Several non-Cartesian partially parallel imaging (PPI) techniques [3, 4] have been proposed to suppress these artifacts. However, inefficient calibration of PPI reconstruction has been a concern in these techniques. In this study, a self-calibration technique was developed for PPI using radial sampling. This technique takes advantage of an intrinsic property of radial sampling and does not need any extra calibration data. It was demonstrated that the streak artifacts can be efficiently suppressed using this method in 2D and 3D (VIPR) radial imaging.

Theory: In radial sampling, an operator effective to streak suppression for a set of radial data with *N* projections can be deduced from the operator that can suppress streaks for the *S* subsets of this radial data with *N*/*S* equidistant projections. For example, consider a set of 2D radial data with *N*=16 projections and let *S*=2. The corresponding PSFs are shown in Fig. 1. Fig. 1(a) is the PSF for 16 projections. Figs. 1(b) and (c) give the PSFs for the two 8-projection subsets of 16 projections. Figs. 1(d), (e) and (f) show the plots of streaks in Figs. 1(a), (b) and (c) in angular direction at a fixed radius. It can be seen that a half of those streaks in the PSF for 16 projections appear in the PSF for one 8-projection subset and the other half appear in the PSF for the other 8-projection subset. These streaks are located at the same positions in the PSFs for 16 and 8 projections, and their amplitudes for 16 projections are lower by a factor of 1/2 than those for 8 projections. Because the streak artifacts in radial undersampling are generated from the convolution of the image and those streaks in the polar PSF, Fig. 1 implies: A half of the streak artifacts in the image generated from the radial data with 16 projections will appear in the image from one 8-projection data subset and the other half will be in the image from the other 8-projection data subset; The artifact level in the image with 16 projections is lower than that in the images with 8 projections by 1/2. Therefore, if an operator is calibrated from the two 8-projection data subsets to the original 16-projection data, this operator will be capable of preserving the real image and suppressing the streaks by 1/2. Furthermore, this operator can be applied to the 16-projection data directly, because the streak positions are the same in the images from the data with 16 and 8 projections. Practically in PPI, one can further downsample a set of undersampled radial data in post-processing to generate several data subsets. A PPI reconstruction operator can then be calibrated from the data subsets to the original data. If one applies this reconstruction operator to the original data, the streak artifacts can be suppressed with the image preserved. Apparently, the higher the number of data subsets is generated, the more the artifacts are suppressed. For this reason, we referred to the number of generated data subsets by downsampling as the suppression factor "S".

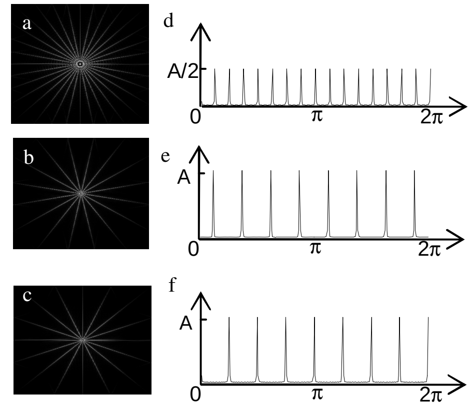

Fig. 1. Polar PSFs for 16 projections (a), first 8-projection subset (b), second 8-projection subset (c), and corresponding plots of streaks in angular direction (d), (e) and (f).

Methods: A phantom image was acquired with 2D sampling trajectory using an 8-channel coil array. Cardiac images were collected using 2D and 3D(VIPR) sampling from a 4-channel coil array. There were 512 projections in phantom data, 256 projections for 2D cardiac images, and 3584 projections for 3D cardiac images. In 2D image, only 1/8 of the projections were used in the reconstruction using RIB [5] with the calibration of artifact suppression. These images were compared with those reconstructed from all the projections using gridding. In 3D image (VIPR), the reconstructed images with artifact suppression were compared with those reconstructed from GRAPPA [4] and gridding.

Results and Discussion: Fig. 2 shows the phantom images. It can be seen that streak artifact level becomes lower and lower as the suppression factor increases. However, a large suppression factor may cause the suppression of image details (small white dots). Fig. 3 shows an example of 2D cardiac images. It can be seen that a clean image with little artifacts can be obtained with a suppression factor equal to 8. Fig. 4 shows the cardiac images using VIPR. With a suppression factor of 4, most artifacts can be suppressed. Compared with GRAPPA, the method in this study is more advantageous in that it can remove the artifacts without blurring the image. These results demonstrate the efficiency of the proposed calibration technique in suppressing the radial undersampling artifacts.

Reference: 1). Scheffler, K. et. al., MRM 40: 474-480 (1998). 2). Peters, D. C. et. al., MRM 55:396-403 (2006). 3) Pruessmann K. P, et. al., MRM 2001;46:638-651 4) Griswold M.A. et.al. ISMRM 2003; Toronto. p 2349 3). Li, Y. et. al., ISMRM 2007, Berlin, p 1752.

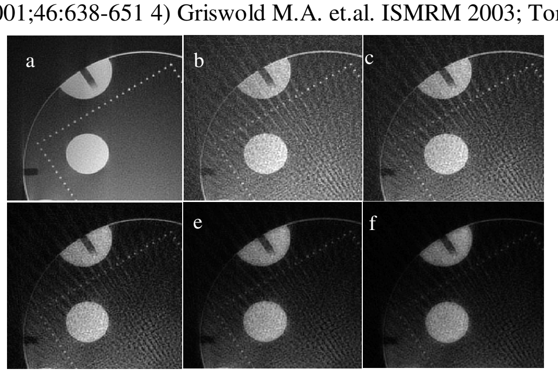

Fig. 2. Phantom images from 512 projections using gridding (a), from 64 projections without artifact suppression (b), and from 64 projections using the calibrated RIB with S=2 (c), with S=4 (d), with S=8 (e) and with S=12 (f).

Fig. 3. Cardiac images from 256 projections (a), from 32 projections without artifact suppression (b), and from 32 projections using calibrated RIB with S=8 (c).

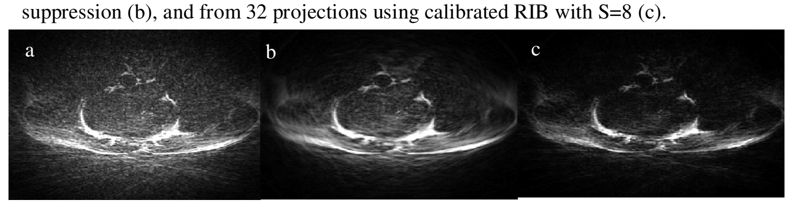

Fig. 4 A center slice of 3D cardiac image (VIPR) reconstructed from 3584 projections using gridding (a), using GRAPPA (b), and using calibrated RIB with S=4 (c).