Highly Accelerated Multislice Parallel Imaging: Cartesian vs Radial

S. R. Yutzy[1], N. Seiberlich[2], J. L. Duerk[1,2], and M. A. Griswold[2]
[1]Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States, [2]Radiology, University Hospitals of Cleveland and Case Western Reserve University, Cleveland, OH, United States

Introduction: Nearly all clinical MR examinations include imaging with multiple slices. Multiband imaging is a hybrid approach between conventional 2D slice and 3D volumetric excitations where multiple 2D slices are excited and sampled simultaneously. This method yields some of the SNR benefits from a larger excitation volume while reducing the artifact potential from a second phase encoding direction, but without further sampling and processing, reconstruction yields a superposition of individual slice reconstructions. While methods have been shown that can separate the slides using parallel imaging for Cartesian trajectories, these methods are not compatible with non-Cartesian sampling. Here we demonstrate the possibility of reconstructing two simultaneously acquired radial slices using an acquisition/reconstruction method known as radial CAIPIRINHA. We show that this method is capable of higher accelerations than possible with comparable Cartesian trajectories.

Theory: In a Cartesian acquisition, the application of a line-dependent linear phase results in a shift of the image in the phase encoding direction, according to the Fourier shift theorem. This has been used in multislice parallel imaging to shift each slice, change the aliasing patterns to ones that are more distinct and thereby reduce g-factor-related losses in image quality [1]. Unlike a Cartesian shift, the application of line-dependent phase in a radial acquisition causes destructive interference in the entire slice [2,3]. Therefore, by extension of rectilinear multi-band concepts, reconstruction of simultaneously acquired multislice radial data with one slice phase cycled would result in an image of slice 1 plus incoherent signal from slice 2 (as simulated in Figure 1, top row). Further, since the phase cycling pattern is known, the phase can be undone in post-processing yielding an image of slice 2 plus incoherent signal from slice 1 (Figure 1, bottom row). The incoherent signal from the other slice(s) can be further reduced by employing coil sensitivity estimates from both slices along with a conjugate-gradient (CG) reconstruction algorithm [4] that reflects the simultaneous sampling and phase cycling process. Here, we compare artifact power (AP) as a function of acceleration in rectilinear and radial multi-band parallel imaging, using equivalent CG reconstruction algorithms.

Methods: All experiments were performed on a Siemens 1.5T system (Espree) in accordance with a local IRB protocol. A standard GRE pulse sequence (TR/TE/α=10ms/4.81ms/15°, THK=5mm) was modified to perform multiband excitation with phase cycling on one band with either a radial or Cartesian sampling pattern. Fully sampled individual images at each slice location were used to generate coil sensitivity maps and for calculation of artifact power. All acceleration factors are reported relative to Cartesian Nyquist sampling (rather than radial Nyquist sampling, which requires a factor of π/2 more lines). Radial and Cartesian scans with two simultaneous slices were acquired with a phase increment of π between lines in the second slice. Retrospective undersampling was performed with in-plane acceleration factors of 1, 3, and 5 (corresponding to 2, 6, and 10 total acceleration including 2x through-plane) and reconstructed with the CG reconstruction algorithm. A vendor-supplied 12-channel head coil was used for reception in all cases; slice excitation centers were separated by 4cm.

Results and Discussion: Cartesian and radial reconstructions are shown in Figure 2. Artifact power for each reconstruction is shown in Figure 3. At low acceleration (R=2), both techniques give a good reconstruction (AP < 10%), with slightly higher quality in the Cartesian scans. At a higher acceleration factor (R=6), the radial sampling scheme gives a visually (Figure 2) and quantitatively (Figure 3) improved/artifact-reduced reconstruction. At the highest acceleration factor (R=10), the Cartesian reconstruction completely fails (AP ~50%) while the radial still gives a usable (although noisier) image (< 20% AP). We believe this is because the center of k-space is still fully sampled in a radial sampling scheme even at high acceleration factors, whereas in a Cartesian scheme the entire k-space is undersampled and must be unaliased.

Conclusions: We have demonstrated that radial CAIPIRINHA can be used to achieve high parallel imaging acceleration in multislice acquisitions. Both radial and Cartesian trajectories give good results at low acceleration factors, while the radial technique maintains image contrast and morphology at high acceleration due to improved g-factor performance and the fact that the center of k-space remains fully sampled.

Acknowledgements: This research was supported by Siemens Medical Solutions and the Ohio Third Frontier Project Innovation Incentive Fellowship.

References: [1] Breuer FA et al, MRM 53(3):684-691 [2] Scheffler K et al, MRM 35(4):569-576 [3] Noll DC, IEEE TMI 16(4):372-377 [4] Pruessmann KP et al, MRM 46(4):638-651

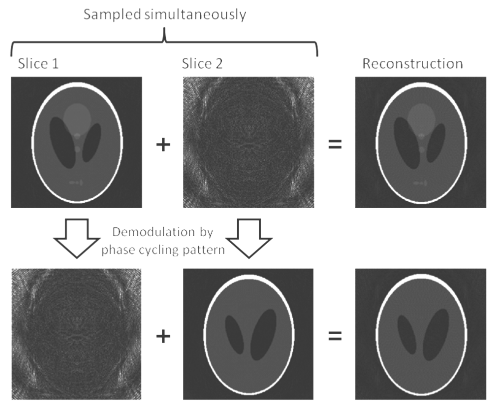

Figure 1 Depiction of two radial slices and how the second slice can be recovered if the phase pattern is known. Additional incoherent signal can be minimized with CG reconstruction.

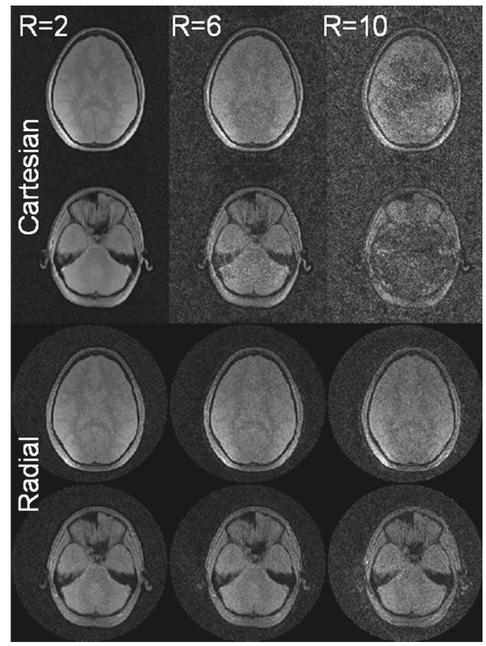

Figure 2 Radial and Cartesian CAIPIRINHA reconstructions for acceleration factors of 2, 6, and 10 using a 12-channel coil and 4cm slice gap.

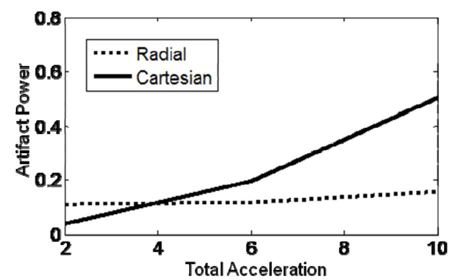

Figure 3 Artifact power of the radial and Cartesian reconstructions relative to fully sampled reference images.