GRAPPA for the 3D Radial Trajectory(VIPR)

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INTRODUCTION

Undersampled non-Cartesian acquisitions can achieve high resolution in a short scan time, but aliasing artifacts reduce contrast for higher acceleration factors. Parallel imaging techniques have been previously implemented to use coil sensitivity information to limit aliasing signal and its impact on CNR for non-Cartesian acquisitions [1]. Initial efforts have concentrated on 2D imaging due to the processing requirements and complexity of 3D non-Cartesian parallel imaging.

The iterative conjugate gradient SENSE (CG-SENSE) method [1], while reasonably successful in improving CNR for the 3DPR sequence known as VIPR [2], is limited by long reconstruction times and a dependence on sensitivity map measurement. The reconstruction drawbacks intensify for time-resolved techniques such as VIPR because none of the calculations from one time frame can be used for another. On the other hand, the calculations for the 2D Radial GRAPPA technique used to synthesize unacquired data can be performed once and then repeatedly applied to different time frames [3]. In this work, we apply and extend the 2D Radial GRAPPA [4] method to 3DPR imaging and demonstrate a significant reduction in aliased signal.

MATERIALS AND METHODS

The fastest CG-SENSE scans allow accelerating a fully sampled scan by the number of coil elements. Radial GRAPPA allows the operator to choose any target scan time and then synthesize additional data equivalent to a longer scan time. Its drawback is that a mask or training scan at this longer scan time is needed. With this drawback, using the technique to image static tissue would hold no value. But the training scan is not prohibitive to improve the performance of dynamic or contrast-enhanced MR angiography (CE-MRA) exams.

While applying Radial GRAPPA to a time-resolved CE-MRA scan is a major objective of this work, we have simplified the development and testing by first applying it to a T1-weighted VIPR abdominal study using a four-receiver phased-array torso coil. All feasibility studies were executed on a 1.5 T scanner (General Electric 1.5T Advantage. GE Healthcare, Milwaukee, WI). An initial training scan was acquired with twice as many radial lines as an accelerated second scan. The first scan acquired N projections, half of which were used as Automatic Calibrating Signal (ACS) lines to calculate the GRAPPA reconstruction weights. The raw data from the training scan was re-aligned along two dimensions as shown in Figure 1 to perform localized GRAPPA. The box slides along the angular dimension, creating a set of reconstruction weights to interpolate data for each coil. When all the regions are calculated for a radial strip, the gray strip is slid horizontally and the process is repeated. These reconstruction weights were used in the second scan to synthesize N additional radial lines.

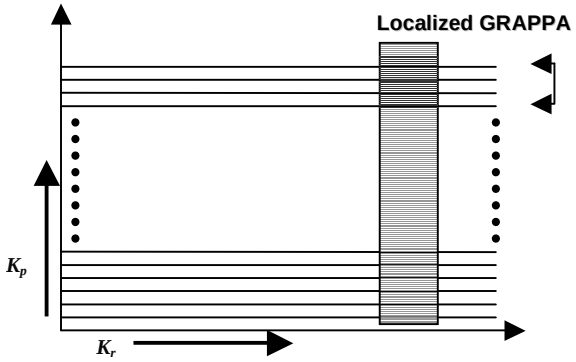

Figure 1. In 3D Radial GRAPPA reconstruction, data from a training scan is used to construct missing lines in k-space. Localized calculations are performed in the dark grey box.

RESULTS AND DISCUSSION

Enhancements in selecting the relevant lines when fitting ACS lines and a singular value decomposition algorithm (SVD) have generated significant image quality improvements compared to results available in [4]. 26,000 radial lines were scanned in the training scan while 13,000 were scanned in the actual scan, giving an acceleration factor of 2. This factor was reasonable when using a four-receiver phase array coil. All processing was implemented offline using a dual-Athlon 1.4 GHz processor. The total reconstruction time was 6 minutes which is a significant improvement over the reconstruction of 60 minutes in [2]. The read out dimension was divided into 32 blocks for the fitting process.

Figure 2 shows the improvement in image quality before and after 3D Radial GRAPPA reconstruction. Image 2(a) is from a 3D VIPR image volume reconstructed using the initial projections acquired in the second accelerated scan. Image 2(b) was reconstructed after additional k-space projections were synthesized using 3D Radial GRAPPA. Figure 3 shows the comparative reduction in mottling in the liver tissue for the same exam in the magnified axial reformat.

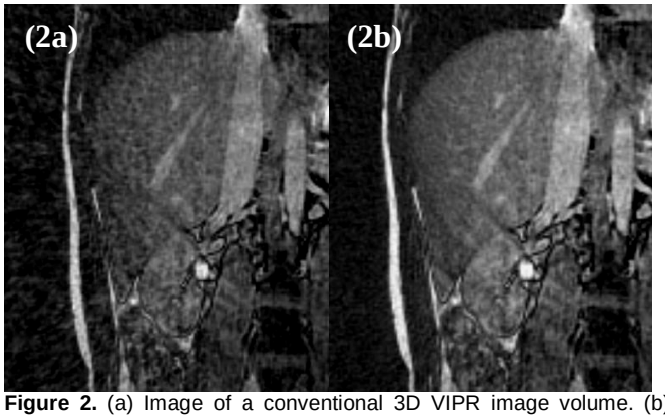

Figure 2. (a) Image of a conventional 3D VIPR image volume. (b) Volume after processing with 3D Radial GRAPPA.

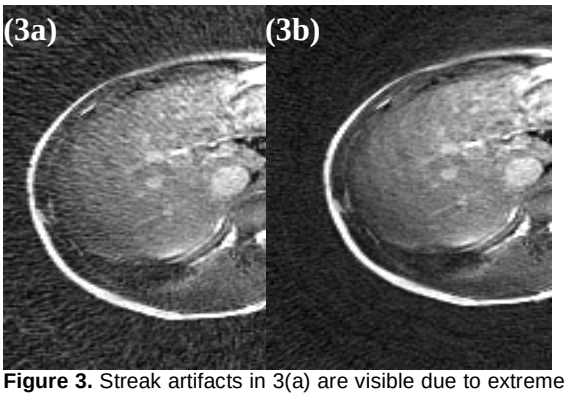

Figure 3. Streak artifacts in 3(a) are visible due to extreme undersampling. 3D Radial GRAPPA processing reduces these artifacts in 3(b) and eases interpretation of finer detail.

CONCLUSIONS

We have demonstrated that a 3D Radial GRAPPA implementation VIPR significantly reduces undersampling artifacts within a reasonable reconstruction time. Future work will extend the method to the multiple echo VIPR trajectory and CE-MRA exams as well as aim for higher acceleration factors using a higher number of receiver coils.

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