Streaking Artifact Reduction in Orthogonal Super Resolution Reconstruction of MRI Data Sets

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Introduction

Super resolution reconstruction (SRR) is a post-processing technique that has been proposed to improve the resolution in the slice-select direction of 2D multi-slice MRI data sets. It is based on reconstructing a high resolution (HR) image from a set of low resolution (LR) image stacks that were obtained from different viewpoints of the same field-of-view. A previously proposed SRR method for MRI was based on the acquisition and reconstruction of three LR orthogonal views [1]. Our group previously observed in SRR images based on three orthogonal views that significant streaking artifacts resulted in the SRR image when the LR data sets were acquired with a slice thickness 6 times greater than the in-plane voxel size. These artifacts are related to the linear interpolation used for upsampling in the reconstruction algorithm. In this study we explored the effect of including an additional LR view at an oblique orientation perpendicular to the through-plane directions of the coronal and sagittal view of the orthogonal geometry in order to reduce these streaking artifacts and improve upon the visual quality of the SRR image.

Methods

A 3D isotropic data set (3DFLASH, T_R=11.3ms, T_E=4.0ms, FA=90.0, FOV=2.2 x 2.2 x 1.2 cm, matrix=512 x512 x 256, navg=4) of a paraformaldehyde fixed E17.5 embryo was used as a biological phantom for simulating the affects of SRR in vivo. This specimen possesses anatomic structures similar to that observed in adult mice and does not suffer from motion artifacts observed in live animal imaging. Three LR 2D multi-slice image stacks (voxel aspect ratio (AR) of 1:1:8 and 1:1:10) were obtained from the high resolution data set by mean subsampling in one of three orthogonal directions (axial, sagittal, coronal). Two additional LR image stacks were simulated at oblique orientations along an axis perpendicular to the through-plane directions (45˚ along an axis perpendicular to the sagittal and coronal orientations). Iterative Back Projection [2] was used for reconstructing the SRR data set from the LR image stacks. Images were visually reviewed and compared to the original HR 3D data set.

Results and Discussion

SR reconstructed images based on three orthogonal views and one additional oblique view resulted in improved visual quality and reduced streaking artifacts in simulations based on LR data sets with voxel ARs of 1:1:8 and 1:1:10. Addition of a fifth oblique view did not improve the visual quality of the SRR image for either voxel AR. Although streaking was still apparent in SRR images reconstructed from four LR views, the streaking was significantly less at high contrast boundary regions such as lung-liver boundary (white arrow Fig. 1c), whereas a typical staircase pattern due to linear interpolation is observed in the 3-view orthogonal SRR (white arrow Fig. 1b). In addition, the stomach wall is well defined in the four-view SRR image (Fig. 1c) and is almost similar to the ground truth (Fig. 1d), whereas the stomach wall from the three-view orthogonal SRR looks blurry (Fig. 1b). This simulation indicates that the quality of an SRR image based on orthogonal acquisition may be improved by the addition of a fourth view acquired obliquely to the through-plane direction of the coronal or sagittal view. Additionally, the observed increase in image quality would be worth the minimal increase in acquisition time required for one additional view.

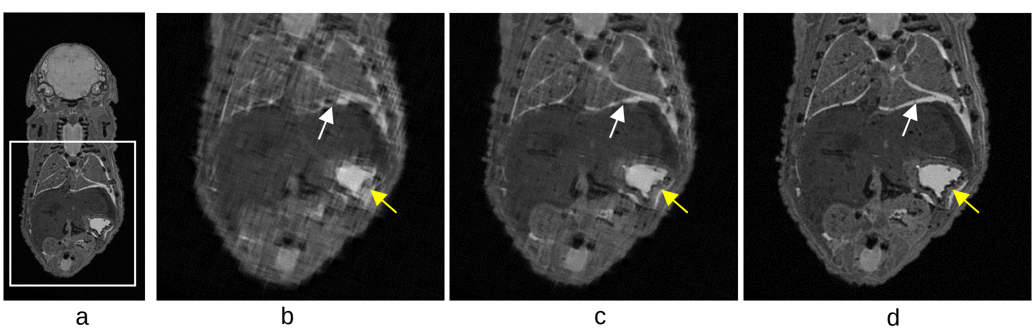

Fig 1, a) Isotropic 3D image, the area enlarged for the comparison is highlighted, b) HR volume simulated from LR image stacks with AR 1:1:10 by 3-view orthogonal SRR (enlarged ROI to show the area of interest) c) HR volume simulated from LR image stacks with AR 1:1:10 by 4-view orthogonal SRR d) Ground truth, isotropic 3D image.

References

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