Undersampled Projection Imaging for Time-Resolved Contrast-Enhanced 3D MR Angiography (PR-TRICKS)

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INTRODUCTION

Contrast-enhanced MRA methods which provide temporal information, such as the 3D-TRICKS technique[1], have tradeoffs between temporal resolution and spatial resolution[2]. Acquiring data with adequate temporal resolution often limits the achievable spatial resolution. It is desirable to have high in-plane resolution along with good temporal resolution.

Recently we have shown that angularly undersampled projection-reconstruction imaging can obtain high resolution images of the vascular anatomy in a short imaging time[3]. Two methods used in Ref. [3] involve hybrid acquisitions with projections acquired in the k_x-k_y plane and Fourier phase encoding in the k_z direction. The first (ZIPR) acquires all k_z phase encodes at each projection angle, potentially producing azimuthal weighting of the k-space data by the contrast agent passage. The second (PRIZE) acquires all projection angles at each k_z phase encoding before moving to the next, producing weighting by the contrast agent curve along the Fourier-encoded k_z direction. However, this method can be difficult to time correctly and only produces a single volume of data during the arterial phase.

We have combined the undersampled projection technique with the previously described 3D-TRICKS method[1] to obtain high in-plane resolution with good temporal resolution and Fourier weighting (PR-TRICKS). Since projections are acquired in the k_x-k_y plane, variable-rate k-space sampling[1] is constrained to the k_z direction. Similar to the PRIZE technique, all projection angles are acquired sequentially at each k_z phase encoding before moving to the next phase encoding.

METHODS

Imaging was performed on a 1.5T system with high-performance gradients (GE Signa EchoSpeed, Milwaukee WI). A conventional 3D-gradient echo pulse sequence was modified to allow projection imaging in the k_x -k_y plane, and division of the k_z (slice) phase encodings into 3 sections, labeled A, B, and C. The lowest spatial frequencies (A section) were acquired twice as often as the other sections (Fig. 1). Images were reconstructed at times corresponding to the acquired sections using interpolation. Resolution in the k_z direction was limited due to the need for high temporal frame rates (< 5 s per frame). This may cause artifacts if the contrast agent concentration changes too rapidly in the k_z dimension.

The abdomens of healthy volunteers were scanned, with a large FOV (40-48cm) in the readout direction, and high readout resolution (fractional echo acquisition of 384 or 512 full-echo points). A 4-channel phased-array torso coil was used; and 92 to 100 projection angles and 18 to 24 slices were acquired. Images were reconstructed using zero-filling, homodyne correction, and filtered back-projection to a 512x512x48 matrix. Informed consent was obtained for all volunteers.

RESULTS

Figure 2 shows sections of coronal maximum-intensity-projection (MIP) images for several time frames in an abdominal exam. High resolution is demonstrated in-plane, and good separation of arteries and veins is achieved. Streak artifacts due to incomplete projections or gradient non-linearities from objects located outside the FOV were sometimes observed, but their effect was minimal on the vessels of interest. Streak artifacts might be reduced with different 3D display projection algorithms, projection trajectories staggered on a slice-by-slice basis, or using the receiver coil placement to restrict the FOV.

DISCUSSION

The combination of undersampled projection-reconstruction methods with the 3D–TRICKS method is able to obtain high in-plane resolution and provide images from 3D volume data sets acquired at several time frames during the passage of the contrast agent. In-plane spatial resolution is higher than that of conventional 3D-TRICKS acquisitions. Slice resolution is lower than the single volume PRIZE technique, but volume data sets can be reconstructed at several time frames during the passage of the contrast agent. The available signal-to-noise ratio (SNR) limits the achievable resolution in the x-y plane and the data acquisition speed. A minimal amount of ghosting in the slice direction was noted in one exam, but did not interfere in the depiction of the anatomy.

REFERENCES

1. Korosec FR, et al., Magn. Reson. Med., **36:** 345, 1996.
2. Mistretta CA, et al., Magn. Reson. Med. **40:** 571, 1998.
3. Peters DC, et al., Proc. 6th ISMRM, 182 (1998).

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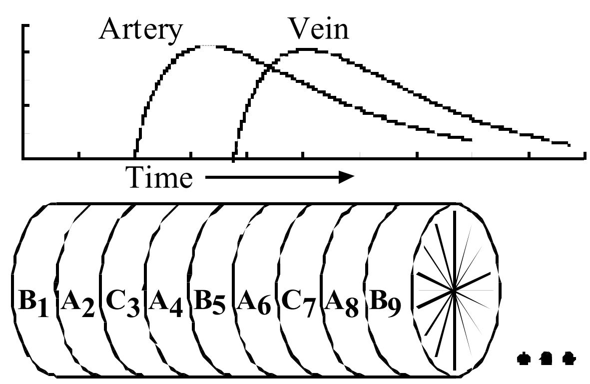

Figure 1: PR-TRICKS data acquisition order.

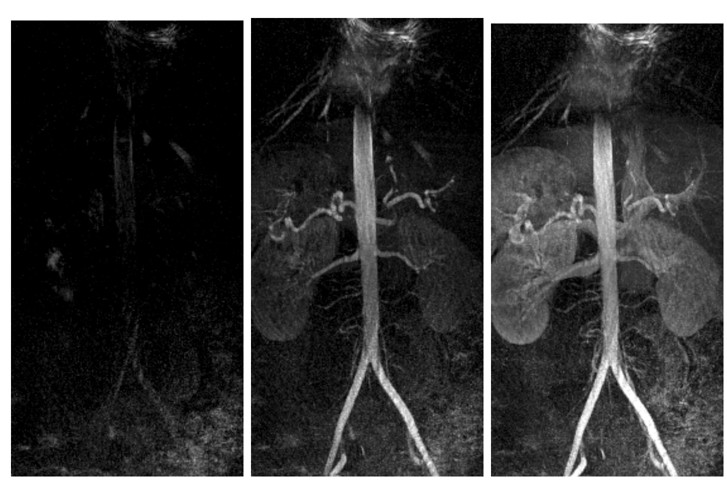

Figure 2: Three non-consecutive PR-TRICKS time frames for an abdominal exam.