Advances in 3D T2-Weighted Projection Imaging

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INTRODUCTION Replacing Cartesian readouts with azimuthally undersampled projections in a 3D RARE echo train was shown to reduce imaging time with tolerable artifacts[1]. Projections cover kx-ky space while Fourier encoding in kz is ordered to provide T2-weighting. Resolution is determined by the projection readout resolution while the number of projections determines the SNR and level of the undersampling artifact. However, the technique was limited by long echo spacing and a maximum echo train length (ETL) of 128. These limited the k-space coverage per excitation, increased scan time, and increased blurring from T2 decay along the echo train.

We present improvements that decrease echo spacing, lengthen the echo train, and reduce artifacts. A particularly interesting application is MR Cholangio-Pancreatography (MRCP). Undersampled projections perform well when high contrast exists between the tissue of interest and the background. The long T2 of bile allows long echo times to suppress background tissue and long imaging times within each excitation. The capability to significantly undersample is demonstrated in MRCP images requiring only 48 projections in the kx-ky space to produce 256 x 256 in-plane resolution. Results are also demonstrated in the brain.

METHODS We have reduced the echo spacing from 8 ms to 5 ms by using shorter non-selective RF refocusing pulses and a shorter excitation pulse. Shorter crusher pulses were also possible with the 40 mT/m peak amplitude and 150 mT/m/ms slew rate gradients on a 1.5T GE CardioVascular (CV) magnet.

The long T2 of bile allows imaging times of approximately 1.2 s [2]. At a 5 ms echo spacing, this would allow 240 echoes to be acquired per excitation, however the pulse programming environment currently limit us to 192 echoes. Our typical MRCP study uses a 24 s breath-hold to obtain eight excitations with a 3 s TR. During each excitation, six projections are acquired at each of 30 slice encodings.

For general T2-weighted imaging, it is desirable to maintain signal over longer echo trains and reduce RF power deposition. We have implemented a ramped train of non-selective RF refocusing pulses with a steady-state flip angle of 110° [3]. The RF power deposition per echo is reduced by more than 65%. The combination of stimulated and spin echoes provide over 80% of the signal level relative to using 180° spin refocusing pulses [4]. Minimal T1 contributions are experienced for most tissue types.

As with all non-Cartesian techniques, projection imaging is sensitive to signal outside the FOV. We use the increased bandwidth capabilities of our CV magnet to double our readout sampling rate and thus double our imaged FOV at no cost in speed or SNR efficiency. This capability significantly reduces our sensitivity to signal outside the desired imaging volume.

RESULTS The MIPs in Fig.1 show the common bile duct and left and right biliary branches in a healthy volunteer. On the left, the image volume was acquired with 1.2 x 1.2 x 2 mm resolution over a 32 x 32 x 6.4 cm FOV. During a 24 s breath-hold, 48 projections were acquired. The right image was obtained in 30 s using fewer slices and 80 projections.

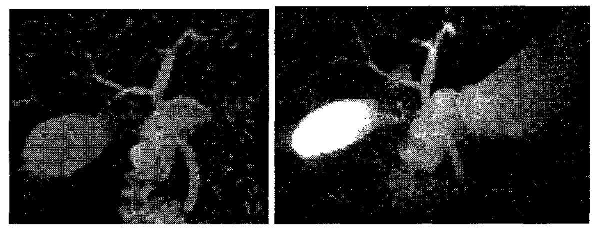

Figure 1: Coronal MRCP MIPs with a 400 ms effective TE. **Left:** 1.2 x 1.2 x 2 mm resolution **Right:** 1.1 x 1.1 x 2.7 mm resolution demonstrates the cystic duct.

General imaging requires shorter echo trains due to the shorter T2 species. The images below were obtained in a 2 minute scan producing 0.78 x 0.78 x 2.0 mm resolution using 120 projections.

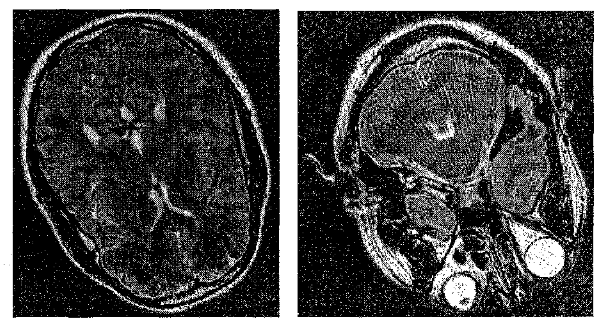

Figure 2: Axial head images using a TE/TR of 200 /2000 ms and a 48 echo train length.

DISCUSSION The limited number of high contrast structures in a MRCP volume make the application well suited for undersampled projection imaging. Varying the resolution is very flexible since it is primarily dependent on the readout resolution. Increases in slice coverage and / or slice resolution could be gained by using a half-Fourier space technique that acquires only a portion of the slice encodes. Increases in SNR efficiency could be obtained by merging the Fourier GRASE method, as demonstrated by Wielopolski [2], with projection readouts.

REFERENCES

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ACKNOWLEDGEMENTS
We acknowledge the funding by Departamento de Física - CINVESTAV-México City; Instituto de Física de la Universidad de Guanajuato; CONACYT grant 141240; and NSF grant BES7908319.