

3D time-of-flight MR angiography with 2D partial Fourier techniques and sensitivity encoding for improved acceleration

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**Introduction** Non-contrast 3D time-of-flight (TOF) MR angiography (MRA) has been widely accepted as a routine clinical tool for evaluation of intracranial arteries. The technique uses the in-flow effect to gain enhancement from the arteries while magnetization transfer and spatial presaturation suppress the signal from the background tissues. With optimized multiple-slab TOF imaging protocols at 3T, it is possible to yield high resolution and excellent signal contrast (1) with 7-10 minute scan times. Use of parallel imaging can reduce scan time by two-fold and skipping the corner of k-space can cut the scan time by 25%. Recently, a 2D partial Fourier undersampling method, CAPR (2), has been combined with parallel imaging for contrast-enhanced MR angiography. It was shown to be robust to undersampling artifacts at high net acceleration. The purpose of this work is to test the feasibility of using CAPR in combination with SENSE to improve the acquisition efficiency of 3D TOF MRA without loss of diagnostic image quality.

**Theory and Methods** *3D TOF imaging method:* All studies were performed on a 3T scanner (GE Signa, v14.0, Milwaukee, WI) with an 8-channel phased-array head coil. A SENSE acceleration factor of two in the phase encoding direction (L/R) was used. Slice and readout directions were S/I and A/P respectively. To achieve background suppression, a SAR-efficient centric magnetic transfer algorithm was incorporated (3). Figure 1 schematically shows the Cartesian ky-kz undersampled CAPR pattern. Only the plane of ky-kz is shown so that each dot in the plane represents a kx echo. A fully sampled central elliptical region contains approximately 30% of total views, while multiple asymmetric radial sectors cover the outer annulus of the plane. All the views are acquired in the EC view order. A FOV of 180mm × 162mm was used with acquired spatial resolution of 0.47×0.83mm. A partial echo with 3.9 ms TE, flip angle of 25°, TR time of 25 ms, and readout bandwidth of ±16 kHz were used. Flow saturation was applied superiorly to suppress the venous return. Three slabs each consisting of 32 1.4 mm axial slices were reconstructed. For reconstruction, zero-filling was used for those non-sampled views. All reconstructions were performed on the MR scanner using the automated in-line proprietary algorithm.

*Phantom experiment:* A cylindrical resolution phantom was used to evaluate spatial resolution in the phase encoding plane. It contained a resolution panel with groups of resolution bars, which was placed in the coronal ky-kz plane. The 2D partial Fourier result was compared to the results from 1D partial Fourier along either the phase or slice encoding direction. All three cases used the same number of views in the central and peripheral regions.

*Volunteer experiment:* With informed IRB consent, a healthy volunteer was scanned using the adapted TOF protocol to evaluate image quality. Three CAPR patterns with various undersampling rate by changing the size of the central ellipsoid region were used and were compared to a fully sampled EC acquisition. The total number of views used in the acquisitions ranged from 70% to 100% of the number of views required for full EC sampling. The undersampling rates, view numbers and scan times for all the sampling patterns are shown in Table 1. The area in k-space covered by central MT for each acquisition was kept the same.

Results

Figure 2 shows the reconstructed images from the phantom study. Only a subset of coronal reformatted images in the Y-Z plane are shown here. The 2D partial Fourier acquisition (a) has better resolved resolution than the 1D partial Fourier cases performed along the S/I (b) or L/R (c) phase encoding directions.

Figure 3 shows the full axial MIPs from the three undersampled CAPR acquisitions and the fully sampled EC view order acquisition. The major arteries in the Circle of Willis and small vessels are well seen in all acquisitions. Even with the total view number reduced to 70%, diagnostic image quality is maintained.

Discussion and Conclusion

We have demonstrated that it is feasible to combine the 2D partial Fourier technique with 3D time-of-flight imaging method to reduce scan time. The CAPR technique resulted in improved spatial resolution as compared to comparable 1D partial Fourier techniques. In vivo experiments yielded 3D TOF angiograms with excellent vessel contrast and high spatial resolution.

**References** 1. Gibbs GF, et al, AJNR 2004; 25(1): 84-87. 2. Haider CR, et al, MRM 2008;60(3):749-760. 3. Lin C, et al, MRM 2008;59(2):434-439

Figure 1: CAPR pattern

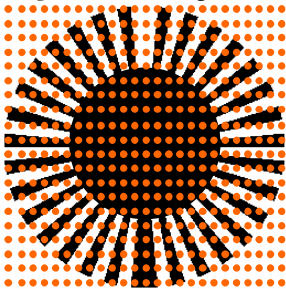


Figure 2 :phantom experiment results

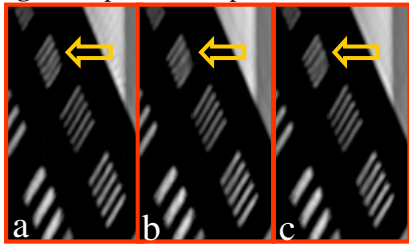


Figure 3: Full axial MIPs from 3D TOF MRA volunteer experiments.

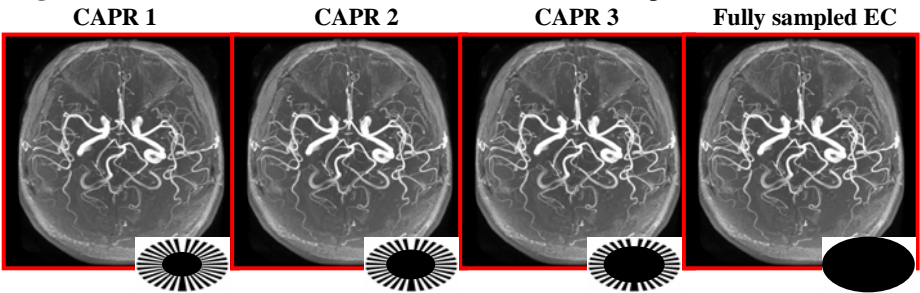


TABLE 1	CAPR 1	CAPR 2	CAPR 3	FULLY SAMPLED EC
Number of views in the central elliptical region	940	1408	1876	2344
Total number of views	1642(70%)	1876(80%)	2110(90%)	2344(100%)
Overall undersampling Rate	1.43	1.25	1.11	1
Scan time	2:40	3:15	3:50	4:30