High Temporal and Spatial Resolution 3D CE-MRA of the Whole Brain

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Introduction: High spatial resolution intracranial MRA is currently routinely performed with reasonable acquisition times using time-of-flight and phase-contrast techiques for a variety of clinical indications. Such techniques, however, lack temporal resolution and are generally of limited usefulness to evaluate dynamic vascular flow, or to completely characterize shunting vascular pathologic processes such as arteriovenous malformations or arteriovenous fistulas. Substantial reductions in the frame time and temporal footprint are needed to adequetely resolve the dynamics of intracranial blood flow. One recently published method attempts to reduce both the frame time and temporal footprint with full radial and azimuthal coverage of k-space by combining partial Fourier and parallel imaging in a Cartesian Acquisition with Projection-Reconstruction-like sampling, termed CAPR [1]. The purpose of this work is to describe implementation of 12x 2D SENSE accelerated CAPR to provide high diagnostic image quality of the whole brain with 1 sec frame times and 3 sec temporal footprint to clearly resolve the intracranial arterial to venous transit of contrast (typically 4-7 seconds).

Methods: All acquisitions were performed in the sagittal orientation, using a 3T MR imager (GE Signa, V14.0) with a custom sixteen-element receive only array. The standard CAPR sampling pattern was modified for 3-fold view sharing in the outer vane set (N3) with center region size of 111 k_Y-k_Z views and imaging parameters: FOV 24.0x24.0x16.8 cm^3, sampling matrix 256 (S/I) x160 (A/P) x84 (L/R) with 4 (A/P) x 3 (L/R) = 12x 2D SENSE, acquired resolution 0.93x1.5x2.0 mm^3, TR/TE 4.376/1.972 msec, BW ±62.5kHz, and flip angle 30°. The frame time was 1 sec and the temporal footprint per frame was 3 sec. A 20 mL bolus of Gd contrast agent was injected at 3 mL/sec followed by 20 mL of saline at 3 mL/sec. The imaging sequence was initiated prior to contrast material injection and continued for 89 frames, resulting in a total acquisition time of approximately 90 seconds. Standard SENSE-homodyne reconstruction was performed offline using automated scripts, returning the data to the scanner console for viewing within 2 minutes of scan completion [2]. Fully 3D non-convex compressive sensing (NCCS) reconstructions (sparsifying transform = finite differences) [3] were then performed offline at a rate of about 1.6 min/frame, or 145 minutes for the 89 acquired frames.

Results: Figure 1 shows oblique MIPs of the whole head reconstructed using NCCS starting one frame after first arterial blush in the carotid arteries. The MIP in (a) is oriented in the sagittal orientation with subsequent oblique MIPs progressing in 12° increments away from the sagittal orientation. The morphology of the intra- and extra-cranial vasculature is well seen. Clear arterial to venous separation is observed over many frames (a-g) during which the arterial vasculature progressively fills. Similarly dynamic filling of the venous vasculature is observed over many successive frames. In no reconstructions were any artifacts observed that would interfere with diagnostic interpretations.

Conclusion: The short 1 sec frame rate and 3 sec temporal footprint of the 12x 2D SENSE-accelerated CAPR acquisition is feasible, with high diagnostic image quality. The ability to resolve the arterial and venous phases of intra-cranial contrast transit is demonstrated. The use of an automated SENSE-homodyne reconstruction allows rapid review of all the source data and sagittal MIPs without delay of clinical workflow. The offline NCCS reconstruction allows for improved image quality and avoidance of non-uniform noise amplification.

[1] Haider, MRM 2008, [2] Borisch, ISMRM 2008, [3] Trzasko, ISBI 2009.

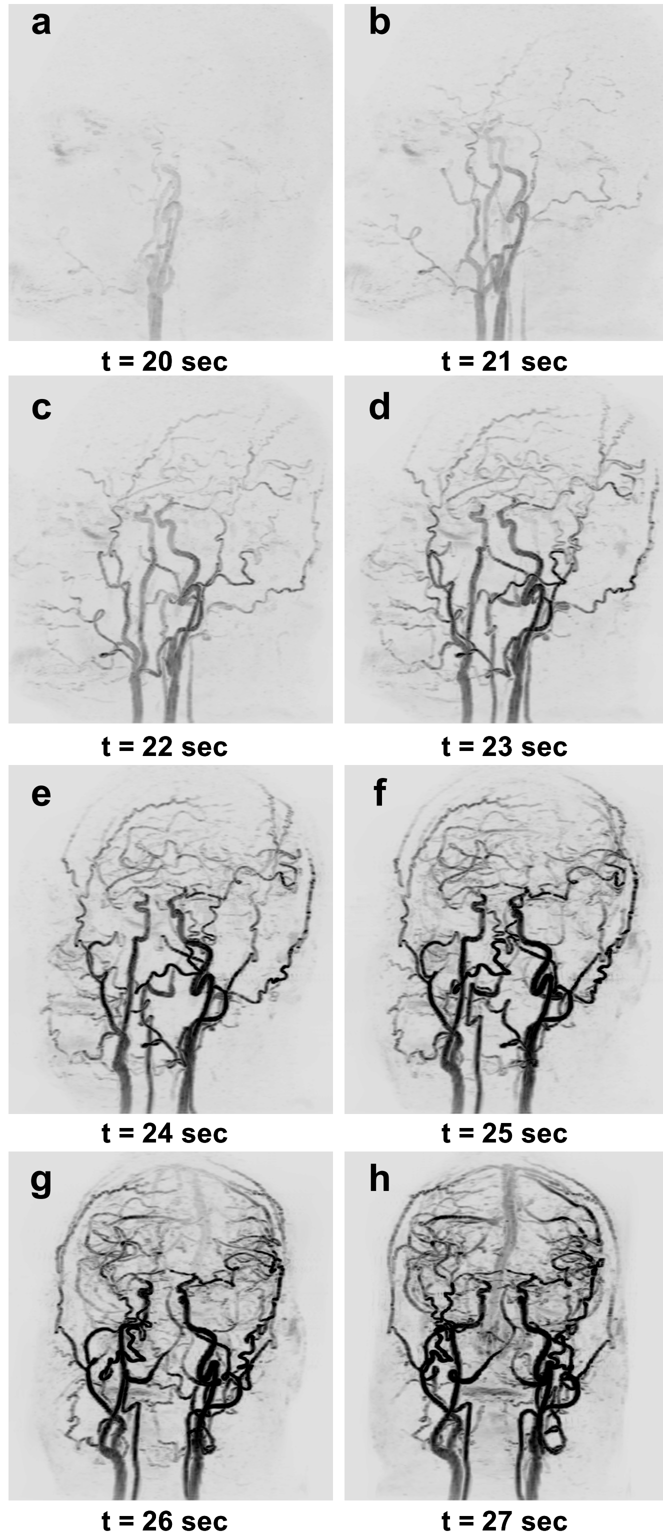

Figure 1. Full-volume oblique MIPs (NCCS reconstruction) shown at acquired 1 sec frame times. The first frame (a) is shown in the sagittal orientation with subsequent frames shown at 12° increments away from the sagittal orientation.