High Temporal Frame Rate 3D Spiral Head and Neck Magnetic Resonance Angiography: Initial Experience

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Introduction: A major challenge for intracranial time-resolved contrast enhanced MR angiography (CEMRA) is the exceptionally short arterial-venous time interval, which is on the order of 4 to 6 seconds [1]. In this work, the feasibility of generating high spatial-temporal update rate dynamic 3D CEMRA using spiral acquisition and the TRACER [2] method (Temporal Resolution Acceleration with Constrained Evolution Reconstruction) is investigated. 3D image volumes were reconstructed at a temporal frame rate between 200 to 300 ms, visualizing the dynamic enhancement patterns in the carotid and intracranial arteries. The high temporal frame rate 4D dataset may enable the measurement of a high quality arterial input function (AIF) for subsequent quantitative functional assessment of the brain.

Materials and Methods: *1) TRACER*: In dynamic MR imaging, when the temporal change in successive frames is small, the temporal update can be recovered even with highly undersampled k-space data [3]. This is done by solving the MR signal equation starting from a high quality initial guess (such as the previous frame when a small change is expected) while constraining the update itself [2, 3, 4]. The problem can be written as $min \; || \, y_n - E_n(x_n) \, ||^2$ or $min \; || \, y_n - P_n F P_{FOV} (\rho_n \cdot c_n) \, ||^2$, where n is temporal frame index, E is the encoding matrix which contains P, the projection of sampling trajectory, F, the Fourier transform, and P_{FOV} the projection onto the field of view. The image content ρ_n is the unknown image at frame n. The problem is nonlinear if the coil sensitivity c_n is unknown as well and can be solved using the well-known Levenberg-Marquardt (LM) nonlinear optimization solver. When solving for ρ_n, the previous frame ρ_{n-1} is used as an initial guess and limited number of LM iterations is used to find the temporal update.

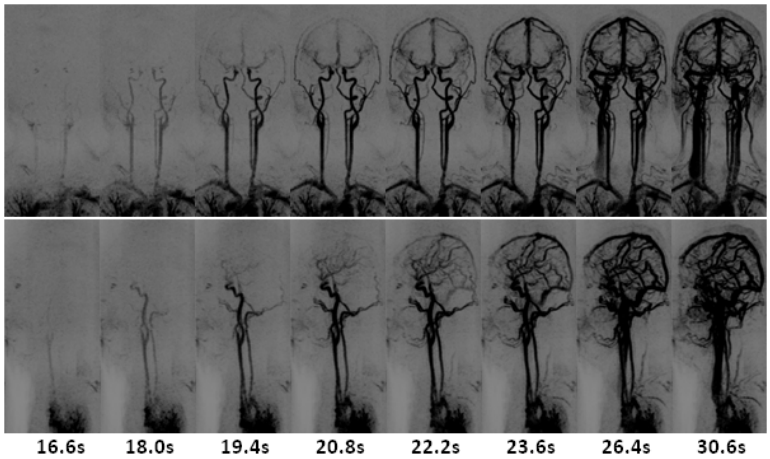


Fig 1. MIP images of coronal and sagittal MIPS at different time points showing the enhancement patterns of the carotid and intracranial arteries.

2) Acquisition and reconstruction: A variable density golden angle ordered stack of spirals were used for data sampling. After obtaining informed consent, 6 healthy volunteers were scanned at 1.5T (GE EXCITE) using an 8-channel head coil (N=3) or an 8-channel neurovascular array coil (N=3). Typical scan parameters were: TR/TE=7.2/0.6ms, FA=25°, BW=±125kHz, FOV=42cm, spatial resolution= 1.25×1.25×3mm^3, coronal imaging plane and acquired matrix size of 336×336×50. Ten ml of gadofosveset trisodium was injected at 2ml/s 20s after scan initiation allowing a fully sampled pre-contrast 3D volume to be acquired. Each dynamic frame was reconstructed for a single spiral leaf (including all slice encodings) using TRACER. *3) Enhancement curve*: After MIP was used to identify the vessels of interest, signal enhancement curves were measured in the 4D CEMRA dataset within ROIs inside the carotid arteries (ROI 1-3 in Fig 3a), middle cerebral artery (ROI4), external carotid artery (ROI5), posterior cerebral artery (ROI6) and the jugular vein. For each curve, a peak width was determined as the difference between the time halfway the enhancement upslope and the time halfway the first downward slope as shown in Fig. 2.

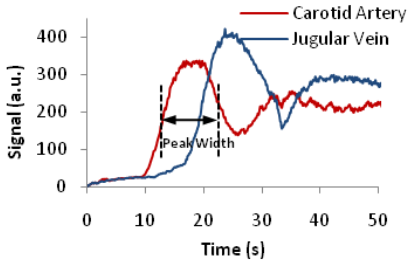
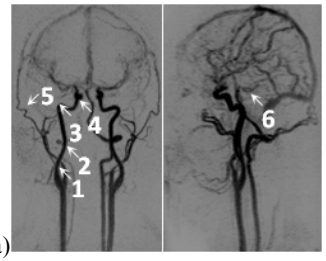


Fig 2. Signal intensity curves of carotid artery and jugular vein.

Results & Discussion In all volunteers, sub-second frame rates MRA of the cranial and neck arteries were obtained. Fig 1 shows coronal and sagittal MIPs at different time points after contrast injection. Enhancement of both large and small arteries at different stages was well observed. The peak widths of carotid artery were 9.21s, 12.4s, and 12.1s and 10.7s, 13.5s, and 14s in jugular vein in the 3 volunteers where both were visible. The contrast dispersion can be seen from the widened jugular vein enhancement curve in Fig 2. Six further signal enhancement curves are shown in Fig 3b. Again, they display the widening of the signal peak width as the distance traveled away from the aorta increases. The peak width from just distal to internal carotid artery origin (ROI 1) to posterior cerebral artery (ROI 6) increased from 12.1s to 17.2s. Within the carotid ROIs (1-3), the peak width did not increase much. For the six ROIs, the time to peak enhancement increased from 11s to 14.1s. Previous simulations [3] have indicated that the reconstructed signal curves may have a ~1s delay with respect to the known curve, but that the signal peak width is not significantly altered.



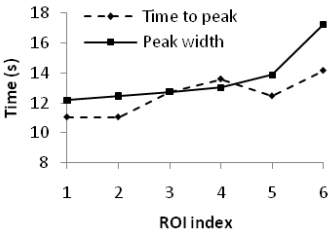


Fig 3. Signal enhancement in one healthy subject a) Position of ROIs (see text). b) Corresponding signal peak widths and time to peak enhancement.

Conclusion: In this work, the feasibility of performing 3D spiral acquisitions with TRACER reconstruction for high frame rate 4D CEMRA of neck and head while maintaining adequate spatial resolution was shown. This enabled the measurement of the signal enhancement curve in various arteries and veins with high temporal sampling, which may enable a more accurate and vessel and territory specific AIF measurement.

References: [1] Klisch J et at. Neuroradiology 2000;42:104-107 [2] Xu et al. ISMRM, Montreal, 2011: 3330 [3] Uecker M et al MRM.60(3)674. [4] Xu et al. MR Angio Club, Banff, 2012