3D MRA with Dynamic Sequence Switching: Improved Imaging of the Arterial and Venous Phases

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Introduction: Imaging of the intracranial arterial system generally requires temporal resolution of about 0.5-3 sec and spatial resolution of about 1 mm isotropic in order to depict most pathological processes. Imaging of the intracranial venous system has less stringent temporal resolution requirements, and thus improved spatial resolution and SNR can be obtained. Time-resolved CE-MRA is one method widely used in imaging of the intracranial arterial system. For imaging of the intracranial venous system a high spatial resolution acquisition timed to contrast bolus arrival [1] is often used. The goal of this work is to combine these two studies into one contrast-enhanced acquisition, and thereby reduce the contrast material dose and the setup and scan time relative to current methods. The specific purpose of this work is to improve the image quality of the arterial and venous phases of an intracranial MRA by dynamically changing acquisition parameters, optimizing spatial resolutions and frame rates as dictated by the relevant physiology.

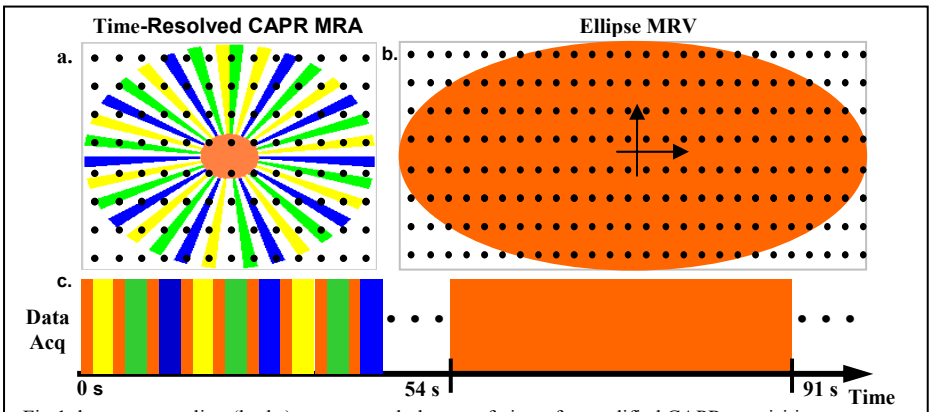

Fig 1. k-space sampling (k_Y-k_Z) patterns and playout of views for modified CAPR acquisition

Methods: *k-space sampling*: The CAPR pulse sequence [2] was modified to allow dynamic change of matrix size, SENSE acceleration, k-space center size, view sharing factor, and sampling pattern at a specified time during the acquisition. A view-shared time-resolved CAPR view order was played out for about 50 sec to capture the arterial phase and contrast bolus dynamics, and then by seamlessly switching to a high spatial resolution sampling pattern and view order, data for a high resolution venogram was acquired (Fig. 1). Studies were performed on a 3T scanner (GE, V14.0) with the standard eight-channel brain array. Acquisition parameters held constant throughout the scan were sagittal orientation, TR/TE 4.25/1.89 msec, flip angle 30º, BW ± 62.4 kHz, FOV 25x25x17.6 cm^3. For arterial phase imaging the CAPR sampling pattern (Fig. 1a) had a view sharing factor of three, 4x 2D SENSE acceleration, and matrix size of 320x160x124 to give an acquired spatial resolution of 0.78x1.56x1.4 mm^3 and frame time of 3.5 sec. For venous phase imaging a full ellipse sampling pattern (Fig. 1b) was used with no view sharing, 4x 2D SENSE acceleration, and a matrix size of 320x320x124 to give an acquired spatial resolution of 0.78x0.78x1.4 mm^3 and an acquisition time of 37.8 sec [3].

Experiments: Eight volunteer studies have been performed using the dynamic change of view order CAPR acquisition. During the first four studies the acquisition parameters for the venogram were altered in order to improve the spatial resolution and SNR. The above parameters were determined to be our optimal working parameters and were used for the remaining studies. In several of these volunteer studies, the standard clinical venogram as used by our institution's Neuro MRI practice was also acquired for comparison with the seamlessly acquired venogram following the MRA. For all volunteers 20 ml of Gd contrast agent was administered at 3ml/sec followed by 20 ml of saline administered at 3 ml/sec.

Implementation of real-time system: In initial volunteer studies the change of acquisition parameters was prescribed to occur after 54 sec, the average time for signal intensity to reach steady state in the intracranial vasculature. In subsequent studies a custom real-time system was used to allow real-time sequence switching on a volunteer-specific basis. The system reconstructs and displays each arterial-phase CAPR image within 0.8 sec of acquisition. Once contrast material had completely filled the venous system, the dynamic change of acquisition parameters was triggered by the user through a real-time GUI.

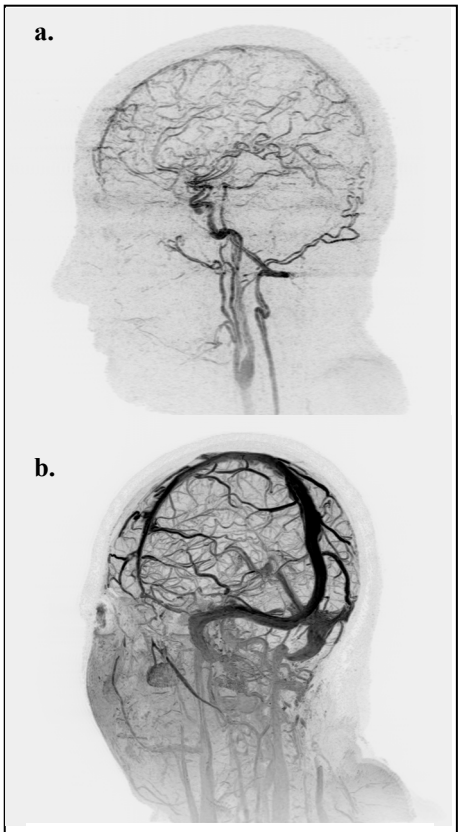

Fig 2. MIPs of one arterial time frame (a) and the subsequent venogram (b) both taken from the modified acquisition.

Results: Fig. 2 shows images from a single contrast-enhanced scan in which several distinct arterial frames (a) were captured as well as a venogram (b). The arterial images are optimized for temporal resolution adequate to resolve the arterial phase, whereas the venous phase accentuates spatial resolution and SNR. With the implementation of the real-time system we are similarly able to obtain high quality images of both the arterial and venous phases, and the timing of the venogram is improved allowing increased vessel signal and reduced skin enhancement.

Conclusions: By dynamically changing view order parameters, the intracranial arterial and venous systems can each be imaged with high quality in a single scan. The implementation of a real-time system for triggering the change of acquisition parameters allows for further reliability by providing the ability to tailor the exam to the specific patient.

References: [1] Farb RI, Radiol 226:203(2003). [2] Haider CR, MRM 60:749(2008). [3] Hu HH, Radiol 243:853(2007).