High Resolution Time-resolved Contrast Enhanced MR Angiography of the Circle-of-Willis using 4X Parallel Imaging

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Synopsis
While 3D time-of-flight is the current method of choice for MR angiography (MRA) of the intracranial arteries, it is time-consuming, taking anywhere from 2 - 6 minutes to acquire, and thus presents a problem for stroke and pediatric patients who cannot hold still during the scan. Contrast enhanced MRA (ceMRA) would be a useful alternative. However, a typical acquisition time of 20-30 seconds means that venous contamination is often observed. Using ASSET parallel imaging with four times acceleration, the acquisition time for each 3D volume can be reduced to 3 - 4 seconds, allowing pure arterial phases to be obtained.

Methods
A 1.5 T Lx 10.0 TwinSpeed MR scanner equipped with an eight-channel phased-array (GE Medical Systems, Milwaukee WI, USA) was used, with a max. gradient strength of 40 mT/m and a max. slew rate of 150 T/m/s. An eight-element flexible array coil was employed (Nova Medical Inc., Wakefield MA, USA), and wrapped closely around the volunteers’ head while avoiding overlapping of the 8 elements as much as possible. A 3D fast spoiled gradient echo sequence was used, and the imaging parameters were: 28-30 cm field-of-view, 256x192 matrix size, TR/TE of 2.4/0.8 ms, 20° flip angle, ±125 kHz receiver bandwidth, 2 mm slice thickness, and 32 slices-per-volume, which was zero-filled to 64 slices in post-processing. In-plane spatial resolution ranged from 1.1x1.5 mm² to 1.2x1.6 mm². Parallel imaging using the Array Spatial Sensitivity Encoding Technique (ASSET), which is similar to SENSE1, was applied with a 4-times acceleration factor to further reduce scan time. Two healthy volunteers (one 38 year-old male and one 35 year-old female) were recruited to validate this technique, each of whom received double-dose gadopentetate dimeglumine contrast material (Berlex Imaging, Montville, NJ, USA) injected at 5cc/sec and 4cc/sec, respectively. An 8 sec delay time was used between the injection of the contrast medium and the start of image acquisition, allowing at least one phase of “baseline” or “mask” images (i.e., prior to the arrival of the contrast material) to be obtained. With an acquisition speed of 3.6 sec and 3.1 sec, respectively, on the 2 volunteers for each complete 32-slice 3D volume, we were therefore able to obtain 8 time-resolved phases of such 3D volumes in a total time of 31 sec and 25 sec, respectively.

Results
In post-processing, the mask images (first of 8 phases) were subtracted from the images from the 2nd to 8th phases for optimal background suppression. The 7 resultant sets of imaging volumes were then further processed using maximum intensity projection (MIP). Fig. 1 shows MIP images of the last 6 of the 8 phases of time-resolved 3D ceMRA images from one volunteer (3.6 sec acquisition time per 3D-volume). A pure arterial phase can be seen in the third phase, as well as the flow from arterial to venous phases, and the “wash-out” of the contrast medium from the arteries.

Discussion
The ability to acquire multiple phases in 3D ceMRA studies of intracranial arteries with high temporal resolution offers tremendous advantages: (i) dynamic flow information can be obtained, allowing, for example, detection of vessel obstructions that merely cause a slow-down in blood flow rather than complete blockage; (ii) any motion artifacts can be minimized, which would be especially useful for stroke patients and pediatric patients; (iii) the need to carefully time the delay between contrast injection and image acquisition can be reduced; and (iv) pure arterial and pure venous phases can both be obtained. While the use of parallel imaging presents the possibility of the generation of artifacts due to the reduced number of phase-encoding lines acquired, such artifacts are minimized by the subtraction of the mask images from the subsequent phases.

References