High Resolution MRA, Imaging M4 and Beyond

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Introduction: The goal of this work is to image the smallest arteries in the brain. It has been previously shown by Venkatesan and Haacke (1) that increasing resolution, although it decreases signal-to-noise (SNR), increases the contrast-to-noise (CNR) and thus enhances visibility. We anticipate by using a contrast agent and very high resolution, it may be possible to see the so far occult smaller arteries that feed the capillaries.

Materials and methods: MRA images were collected at 4.0T using a 3D time-of-flight (TOF) sequence on an eight channel coil with 2x GRAPPA. We scanned at 0.25 x 0.25 x 1.0 mm^3 with and without an MT pulse, and with a Gadolinium contrast agent and no MT pulse. We also scanned at 0.25 x 0.25 x 0.5 mm^3 with and without an MT pulse pre-contrast and with and without an MT pulse post-contrast. We used TR = 73 ms with the MT pulse, TR = 17 without and a TE = 5.66 ms, FA = 20 degrees. Images were examined slice by slice and by MIP to determine small vessel visibility.

Results: The 0.25 x 0.25 x 1.00 mm^3 scans displayed excellent SNR, but without a contrast agent and without MTC the small vessels remained invisible and disappeared into the background. Adding an MT pulse dramatically increased contrast and visibility (figure 1) but required a much longer TR (due to SAR) and therefore a much longer scan time. However, the SNR was high enough to justify increasing the resolution to 0.25 x 0.25 x 0.5 mm^3. At this resolution, we tried injection of a double dose of Gadolinium and no MT pulse to keep scan times shorter (figures 2 and 3). This gave results comparable to a scan with MT and without Gadolinium in a fraction of the time. Finally we tried both Gadolinium and an MT pulse (figures 4 and 5) this gave very good results with many small vessels becoming visible. With this first attempt at very high resolution MRA, smaller branches of the M4 region became visible. Edge definition is also improved. An extra benefit of these high resolution scans is the improved edge definition of major vessels like the middle cerebral arteries which may be important for detecting and measuring aneurysms.

Figure 1: .25x.25x1 mm^3 with MT, no Gad – MIP over 48 slices

Figure 2: .25x.25x.5 mm^3 no MT, with Gad (different subject) – MIP over 72 slices

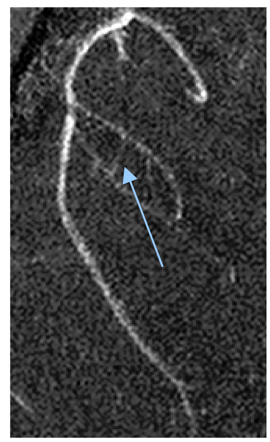
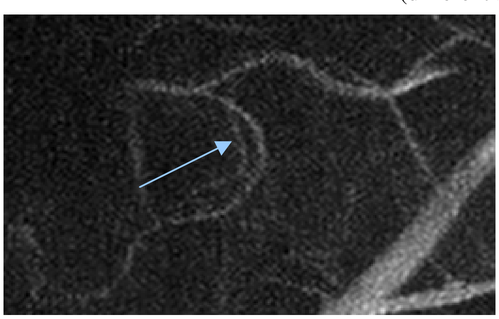
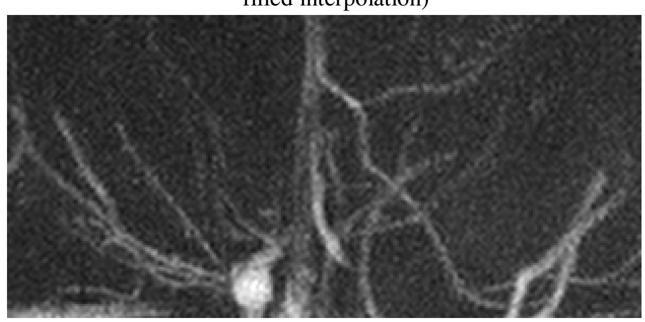


Figure 3: .25x.25x.5 mm^3 no MT, with Gad – MIP over 20 slices with zoom by two (zero filled interpolation)





Figures 4 and 5: .25x.25x.5 mm^3 with MT, with Gad – MIP over 48 slices with zoom by two (zero fill interpolation)

Discussion and Conclusion: Using the above techniques with a resolution of 0.25 x 0.25 x 0.5 mm^3, we were able to better visualize bifurcations past M4 and past what is normally seen with conventional MR neuro-vascular imaging protocols. Despite this progress, there are still many things we can do to improve these results. First, we can change the ordering of the acquisition to reverse centric. This will acquire the high frequencies first, sharpening the edges of the vessels and increasing visibility of the small vessels. Second, we could use MS-325 (which has up to five times the T_1 relaxivity of traditional agents) to increase the signal from the vessels. Third, we can use partial Fourier reconstruction in the read out direction to increase resolution by almost a factor of two (down to 0.125mm) without increasing scan time. The use of these SNR and CNR enhancing methods will enable us to see further branchings of the arterial system. We believe that this will be important to better understand neuro-vascular disease.

References: 1. Venkatesan R, Haacke EM. Role of High Resolution in Magnetic Resonance (MR) Imaging: Applications to MR angiography, Intracranial T_1-Weighted Imaging, and Image Interpolation. International Journal of Imaging Systems and Technology 1997; 8: 529-243.