Pitfalls of Carotid MRA: A Comparison of Time-of-Flight and Contrast-Enhanced MRA

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Image quality in time-of-flight (TOF) MRA may be severely degraded by saturation effects caused by tortuous vessels, disease related turbulence, and slow blood flow. Contrast-enhanced MRA does not suffer from these problems, but requires sufficient contrast, synchronization of the acquisition of the k-space center to the arterial phase, and accurate slab positioning. We present a retrospective evaluation of 63 consecutive patients undergoing both techniques.

Methods

63 Patients (34 female, 29 male, ages 12-92, mean 68) were recruited for evaluation of carotid disease. Both 2D TOF and CE-MRA were acquired during free-breathing. All studies were performed on a 1.5T GE CVi MR scanner with a head/neck neurovascular array coil (MRI Devices).

The scan parameters for the 2D TOF studies were TE/TR 4.7/33.3ms, flip angle 60°, typical acquisition matrix of 256x128x90 to cover a FOV of 20x15x13cm with 1.5mm slices.

Contrast-enhanced data was acquired using a fluoroscopically triggered 3D spoiled gradient echo technique. The 3D acquisition used the following parameters TE/TR 2.0/6.0ms, flip angle 45°, 64kHz receive bandwidth, coronal acquisition matrix of 320x256x32 with partial echo along kx, recessed elliptical-centric view ordering. The field of view was typically 30x21x7 cm to cover the vascular territory from the aortic arch to the Circle of Willis. A single injection of 20cc of Gd at a rate of 1.5 cc/s was used.

Results

Time-of Flight. Signal dropout due to in-plane flow in the distal vertebral arteries at the C1-2 level was observed in 93/126 arteries (74%). Similar signal dropout at loops and tortuous segments of internal carotid arteries (Fig. 1) was observed in 20/126 (16%). Slice misregistration occurred in 41 cases (65%), involving a single slice in 12 (19%), two slices in 3 (5%), three slices in 8 (13%) and more than three slices in 18 (29%).

Gd-MRA. In 1 study (2%), incorrect placement of the imaging volume or patient movement between scans led to one carotid bifurcation being outside the imaging field of view. The carotid bifurcations and vertebral arteries were visualized in the remaining 62 studies (98%). Blurring at the origins of the great vessels and the aortic arch, presumably due to respiratory motion, was observed in 10 (16%) cases.

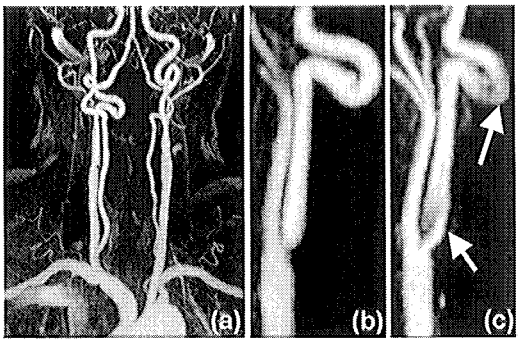

Figure 1. 58 year-old male. (a) coronal MIP of the CE-MRA study, (b) tortuous right internal carotid artery, (c) 2D TOF view showing turbulent dephasing beyond focal stenosis at origin and in-plane saturation at the vessel loop.

Figure 2. 76 year-old female with ulcerated plaque visualized on (a) the CE-MRA study but not (b) the 2D TOF.

Figure 3. 82 year-old male with a long proximal left ICA eccentric stenosis. (a) Gd-MRA, (b) 2D TOF.

Venous enhancement was seen in 9 (14%) studies, although the venous signal was always less than the arterial signal. Selected volume reformatting was found to be sufficient to prevent the venous overlap from obscuring the arteries. Sub-optimal arterial contrast was seen in 2 cases (3%), and in 3 cases (5%) weak arterial ringing artifacts were observed due to the acquisition of the k-space center prior to full arterial enhancement.

Visualization of stenoses. It was found that the degree of stenosis was greater on the TOF images compared to the Gd-MRA in 20 cases. This is likely to be due to post-stenotic turbulent flow causing additional signal loss on the TOF images. In 2 cases stenoses appeared more severe on the Gd-MRA.

Significant findings not visible on 2D time-of-flight that were made on 3D Gd MRA were present in 25 of the 63 patients (40%) including left subclavian stenosis (n=5), right subclavian stenosis (n=3), right subclavian artery aneurysm (n=1), proximal right vertebral artery stenosis (n=9), proximal left vertebral artery stenosis (n=5), and ulcerated plaque at the carotid bifurcations (n=7, Fig. 2).

Discussion

The use of 2D TOF is limited to anatomical regions in which blood flow is fast, and perpendicular to the imaging plane. Additionally, respiratory motion causes slice misregistration, preventing its use in the region of the aortic arch. As indicated by the age range of the study participants, patients referred for the assessment of carotid artery disease are often elderly, with low cardiac output and hence slow blood flow. Furthermore, diseased carotids may lengthen to become tortuous and looped with regions of in-plane or even retrograde flow.

Contrast-enhanced MRA requires the administration of intravenous contrast, is more technically challenging and susceptible to scan prescription and timing errors. However, we find that diagnostic scans were obtained in 62/63 patients (98%). The greater volume covered in the CE-MRA scans frequently revealed significant pathology that would have been missed on routine TOF MRA.