3D TOF MR Angiography at 3T vs. catheter angiography: a quantitative comparison.

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Introduction: Arteriovenous malformations (AVMs) in the brain are complex vascular lesions that are a major cause of hemorrhagic stroke in the young adult population [1]. Catheter angiography (CA) is the current reference standard for imaging AVMs. There has been considerable interest in other less invasive diagnostic methods due to the risks involved in intra-arterial injections and ionizing radiation during CA [2]. In this study we compared MR angiography imaging of AVMs on a 3T scanner against CA. Our objective was to measure (i) nidal maximum linear dimension (MLD), an important parameter in the Spetzler-Martin classification scheme (ii) nidal volume and (iii) the number of venous drainers, using 3D time-of-flight (TOF) with and without contrast-enhancement (CE), and to compare these results against measurements obtained with CA. A 3D contrast-enhance MR digital subtraction angiography (MR DSA) was also performed.

Methods: Forty-one patients (age: mean 38 yrs, range 18-72 yrs, M/F 20/21) with diagnosed AVM who were being treated with stereotactic radiosurgery (STRS) were recruited prospectively. Before STRS, the patients underwent a selective angiogram with a stereotactic frame to help with treatment planning. From this data, nidal MLD, volume and number of venous drainers were measured as described below for MRI. A standard MR imaging protocol was carried out on all the patients within 3 months of their initial treatment on a 3T scanner with a 6 channel SENSE head coil (Intera, Philips Medical System). The 3D TOF was performed once before the injection of the contrast for the MR DSA and once after the acquisition of the MR DSA. Scan parameters for the 3D TOF were: TR/TE = 25/3.3 ms, flip angle 20°, voxel size and dimensions 0.5/111 mm (craniocaudal), 0.525/210 mm (anteroposterior) and 0.75/200 mm (mediolateral). To reduce scan duration, the sequence was performed using a partial Fourier acquisition comprising 70% of total phase encoding values, and a SENSE factor of 2.6 was applied in the phase encoding direction. Scan duration was 7 minutes. The CE 3D MR DSA scan parameters were: TR/TE = 3.7/1.27 ms, flip angle 25°, voxel size and dimensions of 0.96/260 mm (craniocaudal), 1.47/222 mm (anteroposterior) and 2/180 mm (mediolateral). To increase time resolution, keyhole sampling was used. The keyhole percentage was 23%, with high phase encoding steps taken from the first dynamic image. Furthermore, partial Fourier acquisition was used comprising 65% of total phase encoding values, and SENSE factors of 3 and 2 were applied in the phase and slice encoding directions respectively. This gave an effective temporal resolution of 1.9 seconds per 3D frame, and scan duration of 37.2 seconds. Ten mls of Magnevist was injected at 3mls/second using a Spectris power injector (Medrad) approximately 3-4 seconds after the scan was started, to allow acquisition of a reference image for subtraction. The MR images were transferred to the Philips workstation and reconstructed using proprietary software. Prior to visualization, subtraction of the reference image was made on the magnitude images. Two observers who were blinded to the results of the CA findings carried out the image analysis. They measured the diameter of the nidus in anteroposterior, craniocaudal and mediolateral planes using 3D TOF data both with and without contrast. Volume of the nidus was calculated from the diameter measurements on the assumption that the shape of the nidus was ellipsoidal. The number of venous drainers were also measured from the 3D TOF data. Here, the MR DSA was found to be extremely useful for demonstrating AVM flow characteristics. The measured nidal MLD, volume and number of venous drainers were statistically compared with the corresponding measurements obtained from the treatment planning CA data.

Results: The AVM nidus was well demonstrated by the 3D TOF MR angiographic techniques in all the cases. It was difficult to delineate very small AVMs in the 3D MR DSA due to low SNR.

Maximum linear dimension: Paired t-tests showed no statistical difference in MLD measurements for either TOF sequences when compared to the reference CA (non-contrast TOF v/s CA: p value 0.231, 2-tailed; CE TOF v/s CA: p value 0.714, 2-tailed). The scatter plots are shown in Fig 1(a) and (b). These results show that **for MLD measurement, both contrast-enhanced and non-contrast 3D TOF give the same results as CA**.

Volume measurement: Paired t-tests for non-contrast TOF v/s CA showed a significant difference in volume measurements (p value 0.033, 2-tailed), whereas the paired t-test for contrast-enhanced TOF v/s CA showed no significant difference (p value 0.549, 2-tailed). The scatter plots are shown in Fig 1(c) and (d). There is a systematic underestimation of volumes with non-CE TOF v/s CA. These results imply that **for volume measurement, contrast enhancement is required with 3D TOF to give the same results as CA**.

Venous drainers detection: Sixty-four venous drainers were detected with CA. Both 3D TOF with and without contrast were not able to detect all the venous drainers. A paired t-test between non-contrast TOF v/s CA showed a significantly different number of venous drainers (81% detection rate), missing 12 venous drainers, 5 superficial and 7 deep (p value 0.0002, 2-tailed). A paired t-test between contrast-enhanced TOF v/s CA also showed a significantly different number of venous drainers (92% detection rate), missing 5 venous drainers, one superficial and 4 deep (p value 0.023, 2-tailed). A paired t-test between non-contrast v/s contrast enhanced TOF also showed a significant difference (p value 0.007, 2-tailed). These results indicate that for detection of venous drainers, **both TOF methods fail to detect as many venous drainers as CA, but CE-3D TOF performs significantly better than non-contrast 3D TOF**.

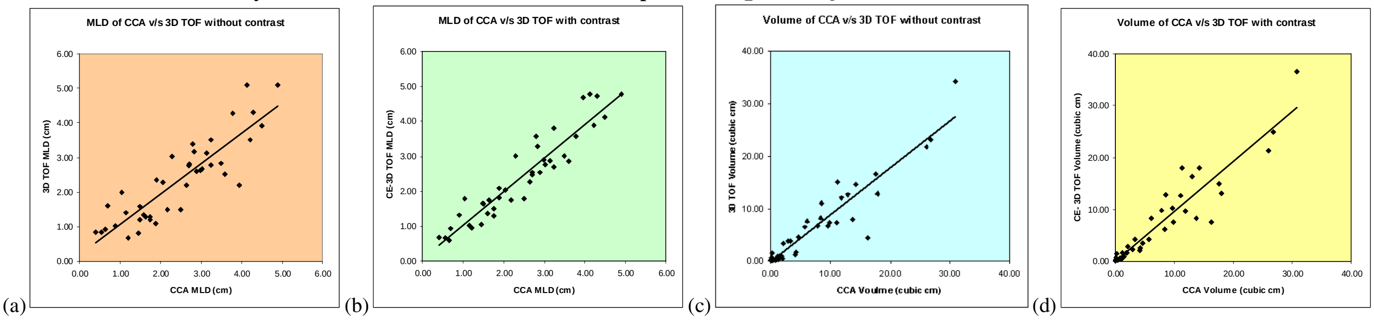

Figure 1 Scatter plots (a) MLD, non-CE TOF v/s CA, Pearson's coefficient 0.88 (b) MLD, CE TOF v/s CA, Pearson's coefficient 0.94 (c) Nidal volume, non-CE TOF v/s CA, Pearson's coefficient 0.94 (d) Nidal volume, CE TOF v/s CA, Pearson's coefficient 0.94.

Discussion: The obliteration of the nidus is one of the main aims of STRS in the treatment of intracranial AVM. Therefore, accurate delineation of the nidus is the prime prerequisite for targeting of intracranial AVM with STRS. Studies carried out on 1.5T MRI scanners show that MRA techniques have been useful in the follow-up of patients after STRS [3-5]. Though these results have been very encouraging they have not been able to replace CA. With advancing technology and the advent of the clinical 3T MRI scanner, there has been a renewed interest in trying to find alternatives to invasive CA. Early reports that higher field strengths have yielded better images with improved spatial resolution [6] have led us to investigate quantitative MR angiographic techniques at 3T in the management of patients with AVM. In this study we found very good correlation of nidal dimensions and volumes as measured by CA and the two 3D TOF MRA techniques. Though the nidal dimensions and volume correlation were very good for the non-contrast 3D TOF MRA we found that quantitatively the nidal volumes were more accurately measured in CE 3D TOF technique. We also found that CA was superior to the MRA techniques for the detection of venous drainers. Of the two TOF methods, contrast-enhanced 3D TOF had a significantly higher detection rate compared with non-contrast 3D TOF MRA.

References:

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