4D Radial-Sliding Window MR Angiograpy of Intracranial Arteriovenous Malformations: Correlation with Digital Subtraction Angiography

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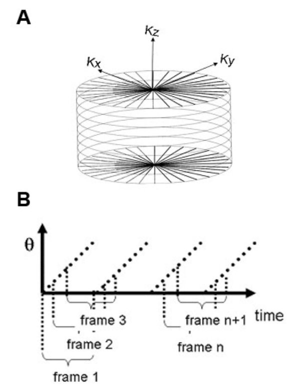
INTRODUCTION

Intracranial arteriovenous malformations (iAVMs) are responsible for the majority of intracranial hemorrhages and confer significant morbidity and mortality in young adults. Expectant management, eventual therapy, and post-procedural follow up of iAVMs require detailed vascular imaging studies to delineate the angioarchitecture of the lesion, the surrounding normal vascular environment, and persistence of the vascular lesion after treatment, namely microsurgical, endovascular, radiosurgery, or combination. The current gold standard for imaging iAVMs involve catheter-based techniques, namely cerebral digital subtraction angiography (DSA), due mainly to its high spatial (0.2mm) and temporal (up to 24 frames/sec) resolution capabilities. However, acquiring DSA images presents some procedural risks to the patient (0.5-12.2%), including risk of thromboembolic complications, vascular injury, and exposure to radiation and iodinated-contrast dyes. Furthermore, iAVM patients likely require multiple follow-up imaging sessions, thus further increasing their exposure to procedural risks. As such, non-invasive imaging techniques have been desired. Recently, CE-MRA sequences have been developed with increasing temporal resolution using novel signal acquisition sequences, e.g., 4D CE-MRA with radial sliding window (4D RS-MRA), which allows the non-invasive acquisition of diagnostic quality images at a high enough frame rate (~6 frames/sec) such that the phases of intracranial circulation are separately captured, allowing the separation of arterial and venous phases. In this technical report, we imaged intracranial AVMs using 4D RS-MRA at 3T and verified the grading of these AVMs between our sequences and DSA from the same patient

MATERIALS and METHODS

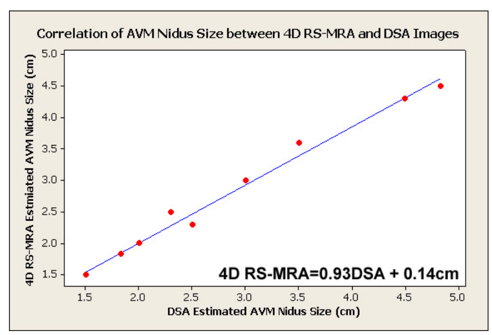
Thirteen consecutive patients with iAVMs either evaluated in the neurovascular clinic with prior digital subtraction angiographic (DSA) imaging or due to undergo stereotactic DSA prior to gamma-knife radiosurgery were enrolled in an IRB-approved study to undergo a 4D RS-MRA. Stereotactic DSA imaging was performed on a Neurostar biplane angiography unit (Siemens, Erlangen, Germany) by selective contrast injection of all territories feeding the iAVM with angiography at 6 frames/sec in standard orthogonal anteroposterior, lateral and oblique projections. 4D RS-MRA was performed on a 3T Whole-body MR-scanner (Trio, Siemens, Erlangen, Germany) within several weeks of the DSA examination. Intravenous gadolinium (0.1 mmol/kg, Magnevist, Berlex, Wayne, NJ) was injected at a rate of 4ml/sec. Our RS-MRA acquisition technique included radial k-space undersampling and pseudorandom view ordering, sliding scale windowing and a sliding mask subtraction technique (Figure 1A,B). We achieved a Field of View (FOV) of 220x220x75mm with pixel resolution of < 1mm and a frame rate of 6 frames/sec. Multiplanar projection maximum-intensity-projection (MIP) CINE images were generated and stored on a workstation. The 4D RS-MRA images were assessed by our team of neuroradiologists, neurosurgeons, and neuroendovascular surgeons blinded to the patient and clinical information. No image sequences were viewed together, i.e., DSA and MRA images from the same patient were viewed weeks apart. An imaging questionnaire was provided to each physician. The interobserver correlation analysis was performed using MiniTab program with a p-value of 0.05.



RESULTS

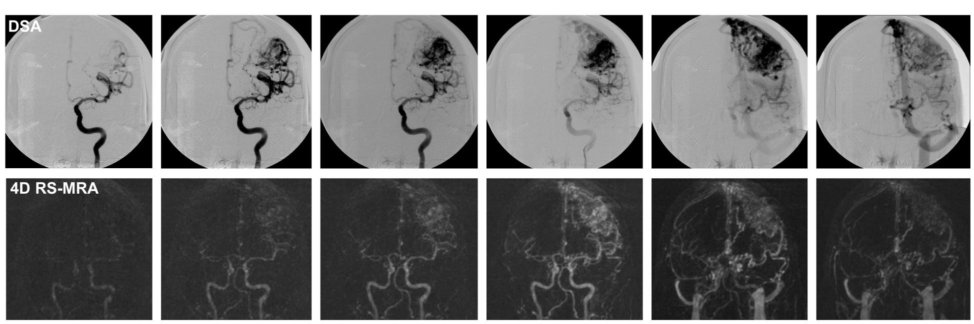
Thirteen patients were assessed by 4D RS-MRA and DSA over a period of 12 months. The patient mean age was 44.2 +/- 14.7 with a male to female ratio of 6:7. DSA demonstrated 10 supratentorial and 3 infratentorial (cerebellar hemisphere) iAVMs.

4D RS-MRA correctly depicted the size, venous drainage and arterial feeders in all cases. Spetzler-Martin grade was correctly determined between raters and between types of scan in all cases except one, where the SM grade was increased according to the DSA images. There was very good agreement between raters regarding identifying arterial feeders, venous drainage, and other vascular anomalies on the individual scans (κ=0.63-1) while the agreement between the DSA and RS-MRA images was also good (κ=0.61-0.85). Two incidental aneurysms were found on both 4D RS-MRA and DSA images. The correlation between DSA and MRA regarding AVM nidus size was very good (Figure 2). Figure 3 demonstrates the image correlation of DSA (top) and 4D RS-MRA (bottom) in a patient example.



CONCLUSIONS

Image analysis of 4D RS-MRA of iAVMs demonstrates equivalency in terms of the Spetzler-Martin scale when compared to DSA. We have developed a 4D RS-MRA sequence capable of imaging intracranial AVMs at sub-millimeter spatial resolution and at a frame rate of at least 6 frames/s, approximating that of DSA. This RS-MRA sequence has the potential to avoid some applications of DSA, thus saving patients from potential procedural risks. Further use of this MRA sequence in different clinical applications is currently underway.



REFERENCES

[1] Greenberg et al. 2007, [2] Cashen et al. 2007, [3] Spetzler and Martin, 1980