Time Resolved MRA of Intracranial AVM patients at 3.0 Tesla: Assessment of Circulation and Transit Times

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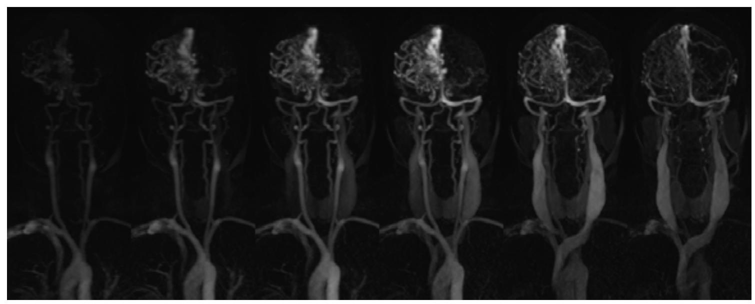
Background and Purpose: Arterio-Venous Malformation (AVM) patients are known to have an elevated risk of complications using conventional catheter angiography (CCA), but nonetheless require monitoring of hemodynamics [1]. We aimed to quantify intra-cranial homodynamic indices non-invasively, using Time Resolved angiography of the carotids and intra-cranial arteries, and to isolate the very transient pure arterial phase of enhancement to define the relevant anatomy.

Methods and Materials: 20 consecutive healthy subject (6 M, 14F 18-70 years old) and 10 AVM patients (6M, 4F, 20-90 year old)) were scanned on a 3.0 T system (Siemens Magnetom Trio) using a fast 3D GRE [2]which incorporated GRAPPA [3] and echo-sharing. Sequence parameters were: TR/TE=2.5/1 msec, FA=24°; BW=750 Hz/Px and an average voxel size of 1.3 × 1 ×3 mm³ and parallel acquisition (GRAPPA X 3). A large field of view coronal acquisition extending from the base of the aorta to the vertex, (500 mm) was performed, encompassing the intracranial and extracranial carotid circulation. A 9 cm slab was acquired with 30 x 3mm partitions. 14 to 16 sequential measurements were acquired during a 20-23 second breath hold, by injecting 4 ml of contrast at 3 ml/sec. In addition, MIP reconstructions were set to be reconstructed online. To further reduce acquisition time, phase partial Fourier (6/8) and slice partial Fourier (6/8) were applied for a linear K-space sampling with zero interpolation resulting in 1.6 seconds time to center of sequential 3D K-space measurements.

For qualitative assessment, arterial enhancement phase were selected from the source data sets. Once chosen, coronal thin MIP (10 mm by1 mm) images were prepared and reviewed throughout the volume. The following supra-aortic arterial branches were evaluated: aortic arch, brachicephalic trunk, subclavian, common carotid, external carotid , internal carotid (four segments: cervical, petrous, cavernous, supra-clinoid), anterior communicating (3 segments: horizontal, sylvian, cortical), vertebral and basilar arteries. Each branch was scored on a 1-4 scale (excellent 1; good 2; fair 3; poor 4) based on vascular enhancement and adequacy for diagnosis. For quantitative assessment, region of interests were placed over the bulb of common carotids bilaterally (right and left-RCC and LCC) and to the sigmoid sinuses of both sides (right and left sigmoid sinus: RSS ,LSS) as well as superior sagittal sinus (SSS). Signal intensity versus time-curves were obtained using dedicated research software (MERZ, Siemens). The software uses a gamma variate fit to calculates mean transit time (MTT), time to peak (TTP), maximal signal intensity (MSI), and maximal upslope of the curve (MUS). Additionally, circulation times for CC to SS and SSS were measured bilaterally.



Results:All studies were performed successfully. All artery branches were visualized in all normal subjects (100%) with good definition (mean = 1.3±0.6). Quantitative analysis is presented in table 1. There was no significant difference (p>0.05) for evaluation of TTP and MTT between left and right vessels (both carotids, and sigmoid sinuses). TTP and MTT were significantly higher in venous structures (RSS, LSS and SSS). There was a very strong correlation (r=0.99, p<0.05) between fitted data and signal (graph 1). Circulation times in healthy normal volunteers detected no significant difference between right and left arterio-venous circulations (p>0.05): LCC to LSS: 7.9 (± 1.2), RCC – RSS: 7.8 (± 1.2); LCC – SSS: 6.5 (± 1.1); RCC – SSS: 6.3 (± 1.2). Details of AVM patients' arterio-venous circulation times are presented in table 2 concerning the location of their AVM.

Table : Measurement of arterio-venous circulation parameters in normal subjects

	LCC	RCC	LSS	RSS	SSS
TTP (sec)	5.7 (±1.7)	5.9 ± (1.5)	9 (± 2)	9.2 (± 1.9)	9.3 (± 1.7)
Maximal SI (units)*	302 (± 243)	272 ± (159)	228 (± 114)	247 (± 106)	416 (± 343)
MTT (sec)	8.0 (± 2)	8.1 ± (1.9)	11.8 (± 2.3)	12 (± 2.5)	11.8 (± 2)
Maximal US (units*/sec)	100 (± 91)	86.9 (± 64.9)	49.7 (± 35)	51 (± 27)	88.7 (± 80.8)

Note: values are presented as mean ± SD. *arbitrary units

LCC= left common carotid; RCC= right common carotid; LSS= left sigmoid sinus; RSS= right sigmoid sinus; SSS= superior sagital sinus

Conclusion: By using dynamic Time Resolved MRA, it is feasible to measure the arterio-venous circulation times and transit time indices non-invasively. Furthermore, by acquiring highly time-resolved 3D data with a very small time footprint, relevant arterial anatomy can be defined in the presence of rapid arteriovenous transit.

Table 2: Report of Indivitual AVM patients' Circulation Times (sec)

	LCC- LSS	**RCC- RSS**	**LCC-SSS**	**RCC-SSS**
L temp	3	7.6	8	7.9
L paraietal	7.5	7.7	7	7
L temp	7.5	6.6	8	8.5
L frontal-temporal	7	5	5.8	5.7
L temporal	5	7.5	5.8	5.7
L paraietal	3	9	9	9
R Frontal	11	8	5.9	5.8
R occ-temp	4	4	4.9	4.8
R Parietal*	5	5	6	6
R Parietal	11	1.9	9	9

*Very large AVM

Reference:

1. **Warren, D.J., et al., 2001.**
2. **Nael, K., et al., 2006.**
3. **Griswold, M.A., et al., 2002**