Studying Brain Motor, Language and Auditory Functions and Associated Functional Connectivity on AVM Patients by fMRI and resting state fMRI

Bob L Hou[1], Majid Haghighat Ahoar[1], Sanjay Bhatia[2], Rachel Lagos[1], and Jeff S Carpenter[1]

[1]*Radiology, WVU, Morgantown, WV, United States,* [2]*Surgery, WVU, Morgantown, WV, United States*

Introduction: Arteriovenous malformations (AVM) lesion cause venous hypertension within the draining vein and relative arterial hypotension in the surrounding brain tissue (1). This “steal effect” in which high blood volume and low pressure in the feeding arteries create hypoperfusion in surrounding normal brain (2) has been reported to lead to brain functional reorganization that functional centers dispersed away from the anatomic lesion (3). In this study, we investigated brain motor, language and auditory functions and associated functional connectivity for AVM patients by fMRI and resting state fMRI (rfMRI). We hypnotized that this condition results in changes (“reorganization”) in brain functions and or in brain functional connectivity. **Material and Methods:** Four AVM patients (2 males and 2 females 56.3± 5.4 years) were included in this abstract. The all lesions were located in or adjacent to the left MCAs. The MRI scans were performed on a 3.0 T Siemens MRI scanner with a 12 channel head coil. After a T1-weighted high spatial resolution imaging using a MPR_TRA_ISO pulse sequence (TR/TE: 1900/2.99ms, slice thickness: 0.9 mm and 160 axial slices for covering whole brains), rfMRI and fMRI imaging were performed by using a multi slice 2D EPI (TR/TE: 3000/30ms, field of view (FOV): 190 mm, image matrix: 64*64, slice thickness: 4 mm, 38slices) for total 100 volumes. For the rfMRI scan, the subjects were asked to close their eyes, and “rest” during the rfMRI scans. For the fMRI scan, a boxcar paradigm with 5 on and 5 off and 10 repetitions was applied. The subject was asked to perform a task such as finger tapping, word listening, verb generation in the “on” periods, and resting (i.e., do nothing and keep mind “wandering”) in the “off” periods. rfMRI and fMRI analyses were performed by using FSL (4) and AFNI (5). Group independent component analyses (ICA) were performed by FSL, and the components (i.e., the networks) related to sensory motor (SM), language (L) and auditory (A) systems were found from the ICs, then the SM, L and A maps for the AVMs were exported to AFNI to get the mean Z scores of the networks and the activation volumes. The ratios of the Z score and activation volume for AVM side (i.e., the left side) over non AVM side were calculated. The individual analyses were done in AFNI. First the functional cortices maps for SM, L and A were determined from the fMRI data by a GLM correlation analysis, then the functional connectivity maps for the SM, L and A were determined from the rfMRI data by applying a seed, based on the highest signal areas in the corresponding functional map, method. The means and standard deviations of correlation coefficient (r) and signal% for fMRI data or activation volume for rfMRI data for both the left (i.e., the AVM side) hemisphere and the right (i.e., the normal side) hemisphere were calculated. A two tail, equal variance, t-test was applied to the data of the left hemisphere and the right hemisphere to get P values. $P < 0.05$ was set as significant. **Results:** Fig. 1 displays the maps of function and functional connectivity of SM, A and L for the AVM group, and the corresponding maps for an AVM case. Please note the maps of the individual (the 2nd row) are the mirror position of the group maps (the 1st row). The motor functional areas demonstrate normal bilateral pattern (see the leftist two images in the 1st row). However the functional areas for auditory are dominated in right hemisphere. The corresponding connectivity maps for SM (the 4th leftist in the 1st row) and A systems show bilateral patterns but the functional connectivity areas for SM are more posterior to the corresponding functional ones. For language (L) system, both function and functional connectivity maps suggest a dominated left language areas with a big Broca’s and small Wernicle’s areas. In Table 1 the data are the ratios ((AVM)/ (non AVM)) of activation volume and Z score for the SM, A and L systems in the maps of fMRI and rfMRI for the group. The ratios of SM are approximate to one: suggesting the sensory motor system is intact to the AVMs. The ratios for language (L) system are greater than one, suggesting that dominate language areas are still in left hemisphere even though an AVM is nearby. The ratios for auditory function are less than one, suggesting that the auditory function is mainly in non AVM hemisphere. Table 2 lists mean correlation coefficient: r value and signal % or activation volume in AVM and non AVM hemispheres and the corresponding P values for the SM, A and L systems in the maps of fMRI and rfMRI of each AVM case.

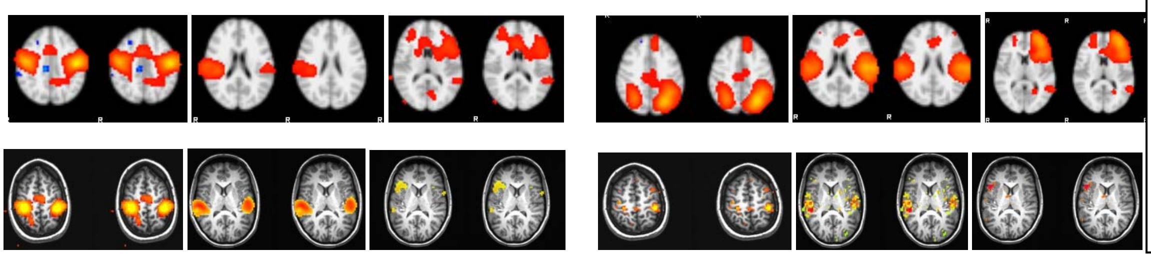

Fig. 1. The functional (left) and functional connectivity maps (right) for sensory-motor, auditory and language (from left to right) for the AVM group (the first row) and for an AVM case (the second row). Please note the hemisphere for the second row is the mirror hemisphere in the first row.

Table 1(Left). Ratios ((AVM)/(N-AVM)) of activation volume and Z score for the SM, A and L systems in the maps of fMRI and rfMRI for the AVM group.

	Ratio (Act. vol.)			Ratio (Z score)		
	SM	A	L	SM	A	L
fMRI	1.00	0.20	3.00	1.00	0.46	2.00
rfMRI	1.20	1.00	8.00	1.15	1.20	3.00

Table2 (Bottom), Mean r value and (sig % or activation volume) in left (i.e., the AVM side) hemisphere and right (the n-AVM side) hemisphere and the corresponding P values for the SM, A and L systems in the maps of fMRI and rfMRI of each AVM case.

	r value			Sig % for fMRI; Act Volume (abs) for rfMRI		
	SM	A	L	SM	A	L
fMRI (n-AVM)	0.67±0.14	0.66±0.18	0.63±0.12	1.53±0.76	0.88±0.12	0.94±0.11
fMRI (AVM)	0.67±0.16	0.53±0.20	0.41±0.24	1.23±0.60	0.59±0.063	0.56±0.24
P(fMRI)	0.970	0.002	0.059	0.350	0.022	0.055
rfMRI (n-AVM)	0.72±0.19	1.88±0.28	0.90±0.13	118.75±125.19	175±55.67	92±21.67
rfMRI(AVM)	0.67±0.18	1.26±0.27	0.56±0.09	51.25±37.05	95±10,05	14.5±4.2
P(rfMRI)	0.630	0.044	0.017	0.460	0.049	0.004

Discussions: fMRI signal is linked to cerebral blood flow (CBF) (6), but the presence of an AVM results in marked aberrations of CBF. The functional areas’ and or signal’s changes for an AVM case may result from functional reorganization or simple byproduct of CBF redistribution. In this study, all AVMs were in the perfusion territory of the left MCAs and adjacent to the left primary auditory cortices (PACs). The functional maps for the auditory (Fig. 1) and the ratios for the auditory function (i.e., the fMRI (A) in Table 1) suggest a reduced signal in the left PACs. This decreased signal is further evidenced by the data in the Table two when we compared the values of r and signal% in AVM side with non AVM side for each AVM’s auditory fMRI data, the corresponding P values for r and signal% are 0.002 and 0.022, respectively. The corresponding functional connectivity in the auditory system was also demised in the AVM hemisphere (P (r) = 0.044, and P (act. V.)= 0.049). The P values for SMs determined from fMRI or rfMRI suggest no difference in the SM cortices of AVM hemisphere. For the language system, the images in Fig. 1, data in Tables one and two (only P(rfMRI)) suggest a normal dominated function in left hemisphere, i.e., the AVMs may not, since P(fMRI)s for L system are just larger than 0.05, influence language function. **Conclusion:** Our results suggest the AVMs in left MCAs reduced fMRI signal and functional connectivity in left PACs. This reduction can link to either functional reorganization or CBF redistribution. **References:** [1] The AVM Study Group, N Engl J Med, 1999, 1812-1818.[2] Lantz ER and Meyers PM, Neuropsychol Rev, 2008, 167-77. [3] Bambakidis NC, et. al., Neurosurg Focus, 2001. [4] RW, COX, Computers and Biomedical Research, 1996, 162-173. [5] Smith, SM., et. al., NeuroImage, 2004, 208-219.[6] Buxton, RB, et. al., Neuroimage, 2004, 23 Suppl 1:S220-33.