

Measurement of DTI metrics in Hemorrhagic Brain Lesions: Its possible implication in imaging interpretation

M. Haris¹, R. K. Gupta¹, N. Husain², K. M. Hasan³, L. Pal⁴, P. A. Narayana³

¹Department of Radiodiagnosis, Sanjay Gandhi PostGraduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India, ²Department of Pathology, King George's Medical University, Lucknow, Uttar Pradesh, India, ³Department of Diagnostic and Interventional Imaging, University of Texas Medical School at Houston, Houston, Texas, United States, ⁴Department of Pathology, Sanjay Gandhi PostGraduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

Introduction: Evolution of intracranial hemorrhage in the brain parenchyma as well as in the tumor tissue has been extensively studied on conventional magnetic resonance imaging (MRI)¹. Diffusion weighted studies (DWI) in different stages of the hemorrhage have been reported with conflicting results. Diffusion tensor imaging (DTI) derived quantitative measures reflects the integrity of white matter fiber tracts by taking the advantage of the intrinsic properties of water diffusion in human brain tissue. We report an unusually high fractional anisotropy (FA) values within intracranial hemorrhage and hemorrhagic lesions in 22 patients, and explain the possible biological mechanism responsible for this remarkable observation.

Materials and Methods: DTI was performed as a part of routine workup on the patients presenting to us for the evaluation of various intracranial mass lesions for the last two years. We selected 22 patients with cerebral hemorrhage (CH) (n=16, mean age 32.7±17.0 years) and hemorrhagic brain tumor (HBT) (n=6, mean age: 31.2±17.6 years). Nature of hemoglobin present in each case of cerebral hemorrhage and hemorrhagic brain tumors were characterized based on the variable signal intensity patterns on T1 and T2 weighted images. Conventional MRI and DTI of brain were performed on a 1.5 Tesla GE MR scanner using a standard quadrature head coil. DTI data was acquired using a single-shot echo planar dual spin echo sequence with ramp sampling. The acquisition parameters were: TR=8sec/TE=100ms/number of slice=36/slice thickness=3mm/interslice gap=0/FOV=240mm image matrix=256×256 (following zero-filling)/NEX=8/diffusion weighting b-factor=1000 s-mm². The DTI data was processed as described elsewhere² for region of interest (ROI). We have also obtained DTI data from 18 normal volunteers, ex-vivo blood and blood clots. The DTI data of blood clots in four tubes were obtained at 24 hours, 48 hours, one week, and subsequently every week up to eight weeks. Finally, the tissue sections of one case of cerebral hemorrhage that was removed with clinical suspicion of glioma, hemorrhagic brain tumors, and blood clot of four tubes were analyzed histopathologically.

Results: We report four stages of hemorrhage i.e. acute, early subacute, late subacute, and chronic in both CH and HBT. The mean FA and mean diffusivity (MD) values in these stages are summarized in the table. The mean FA and MD from the periventricular white matter in normal volunteers was 0.31±0.068 and (0.71±0.044) ×10⁻³ mm²/sec. We obtained a significant decreased FA values with significant increased MD from acute to chronic stage of CH while in case of HBT the FA values were not significantly changed between different stages with inconsistent change in MD. The FA value of blood clot showed an increase up to 7th day and then decreased as a function of time. The mean FA with MD values of ex-vivo blood clot was (0.24±0.018) and (0.50±0.030) ×10⁻³ mm²/sec at 7th day. Histological analysis of hemorrhage in HBT showed intact red blood cells (RBCs) along with fibrin in early subacute stage, both intact and lysed RBCs with fibrin mesh in late subacute stage, hemosiderin laden macrophages and extracellular hemosiderin entangled within fibrin mesh in chronic stage of HBT. In early subacute stage of CH both intact and lysed RBCs with well-formed fibrin mesh was evident. Histology of the ex-vivo blood clot showed, band of fibrin with few entrapped intact WBC edged on both sides by RBCs at 24 hours, plenty of intact RBCs with fibrin network at 48 hours, both intact and lysed RBCs with well organized fibrin was evident at 7 days, amorphous tissue with strands of fibrin seem to be dissolve at 8 weeks.

Discussion: We suggest that intact RBCs with fibrin mesh orient along the principal eigen-vector and result in high FA with low MD in acute and early subacute stage while in late subacute and chronic stage these structural patterns begin to disappear, resulting in increased MD with decreased FA, in case of CH. The FA was highest in 7th day ex-vivo blood clot, suggests that both intact RBCs and fibrin mesh were responsible for increased anisotropy which start to decrease as a function of time, due to lysis of RBCs and disappearance of fibrin mesh. Our explanation for high FA and low MD in acute and early subacute stage of HBT was similar to those for CH. Low ADC value in late subacute stage of HBT has been reported to be due to blood cells debris and viscosity impeding water diffusivity³. In late subacute stage, intact RBCs with fibrin mesh was responsible for increase FA and low MD. Local field gradient in the presence of paramagnetic substances are also known to be responsible for increased anisotropy⁴. The high FA with low MD in chronic phase of hemorrhagic tumor can be explained on the basis of combine role of fibrin and paramagnetic effect of intracellular hemosiderin. In chronic stage of cerebral hemorrhage, hemosiderin was extracellular and thus no more anisotropy was there on applying local field gradient and hence low FA with increase MD was evident. We suggest that the presence of hemorrhage in the tumor may simulate the compressed fiber tracts and may confuse the surgeon in planning of tumor resection as DTI is being used currently in the surgical planning of tumor resection. As the FA values are significantly lower in the late subacute and chronic stage of CH compared to HBT, it may be of value in differentiating hemorrhage from hemorrhagic tumors using DTI.

Pathology	Acute stage		Early subacute		Late subacute		Chronic	
	FA	MD*	FA	MD*	FA	MD*	FA	MD*
Cerebral hemorrhage	0.30±0.10	0.51±0.21	0.28±0.09	0.64±0.18	0.17±0.06	0.94±0.28	0.17±0.06	1.12±0.46
Hemorrhagic brain tumor	0.33±0.06	0.50±0.15	0.31±0.05	0.63±0.21	0.33±0.08	0.70±0.18	0.32±0.06	0.44±0.16

*MD is expressed as ×10⁻³ mm²/sec.

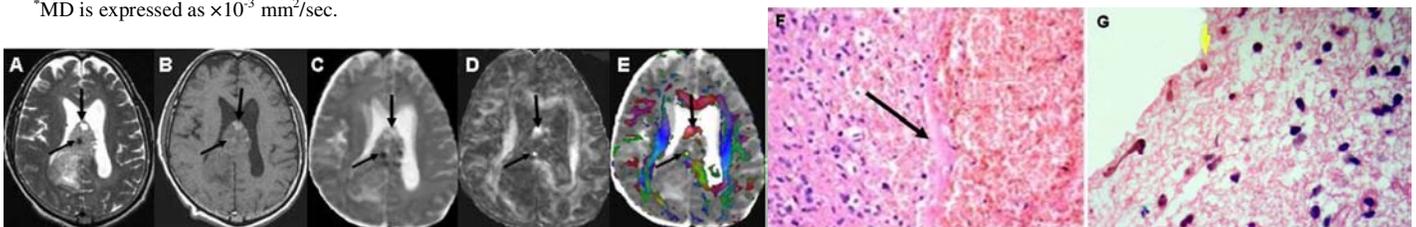


Figure 1: Excised hemorrhagic brain tumor showing two different evolving patterns of hemorrhage i.e. late subacute and chronic stages appearing hyper and very hypointense on T2 (A), hyperintense and isointense on T1 (B), increase and low MD (C), High FA (D) and RGB map of FA (E) showing high colour region. On histopathology this tumor confirmed glioblastoma multiforme with hemorrhage. Two different structural patterns of RBCs are seen on histopathology, one consists of both intact and lysed RBCs with fibrin mesh (F), other region showing hemosiderin-laden macrophages and extracellular hemosiderin entangle within fibrin mesh (G).

References: 1. Bardley WG. Radiology 1993;189:15-26. 2. Hasan KM, et al. J Magn Reson Imaging 2005;21:735-743. 3. Mori H, et al. Acta Radiologica 2002;43:563-566. 4. Xia Z, et al. Journal of Biomolecular NMR 2000;17:167-174.