Predictive value of Diffusion Tensor Imaging (DTI) Metrics and In Vivo Proton MR Spectroscopy (PMRS) in the Differential Diagnosis of Cystic Intracranial Mass Lesions

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INTRODUCTION: Accurate diagnosis of cystic intracranial mass lesions is imperative as the management varies from simple needle aspiration in abscesses to complete resection in tumors. These lesions show ring enhancement irrespective of the etiology on conventional magnetic resonance (MR) imaging. In vivo proton MR spectroscopy (PMRS) and diffusion weighted imaging (DWI) individually or in combination have been used in its differentiation with some success (1). Presence of amino acids along with lactate is considered the signature of the brain abscess while lactate along with choline suggests neoplasm (2). Low apparent diffusion coefficient (ADC) in a cystic cavity helps in differentiating abscess from tumors. However, the absence of amino acids on PMRS and lack of restriction in the abscess cavity on DWI has been well reported (1, 3). High fractional anisotropy (FA) values have been demonstrated in patients with brain abscess on diffusion tensor imaging (DTI) with variable mean diffusivity (MD) values (4) suggesting that it may also be useful in the discrimination of these cystic mass lesions.
In the current study we have performed both in vivo PMRS and DTI in 53 patients of intracranial cystic mass lesions prospectively with an aim to assess the efficacy of these non-invasive MR techniques to precisely characterize the nature of the lesion in these patients.

MATERIALS AND METHODS: 53 patients with intracranial cystic mass lesions were studied over a period of 18 months. After clinical evaluation, all the patients were subjected to MR imaging and spectroscopy. Inclusion criteria for all these patients in this study were cystic lesions with rim enhancement on conventional MRI. Besides this, 10 age and sex matched healthy controls were also included in the study. **MR imaging Protocol:** Conventional MRI and DTI of all the patients were performed on a 1.5 Tesla GE MRI 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/slice no.=34/slice thickness=3mm/interslice gap=0/FOV=240mm image matrix=256x256 (following zero-filling)/ NEX=8/ diffusion weighting b-factor=1000s/mm^2. The diffusion tensor encoding used was the balanced, rotationally invariant dodecahedral scheme with 10 uniformly distributed directions over the unit hemisphere. DTI data was processed by using JAVA based in-house developed DTI-toolbox. (5) In vivo PMRS was done by using a water suppressed localized single voxel spin echo (SE) sequence with TR/TE = 3000ms/ 35ms and voxel was placed with great care to avoid its contamination with surrounding lesion wall and other perilesional area. **Quantification of DTI Data:** For FA and MD quantification, rectangular regions of interest (ROIs) were placed inside the lesion in each patient on the FA maps overlaid on MD. A minimum of 6 slices were selected for ROI placement and mean of FA and MD from all the 6 slices were then considered for further analysis.
For spectral analysis, various spectral peaks of different metabolites in proton MR spectrum were identified. Frank pus on neurosurgical procedure for abscesses and histopathology of biopsy samples for other cystic lesions was considered as gold standard for their confirmation. The criteria for abscess diagnosis were low diffusivity (MD $\leq 0.9 \times 10^{-3}$mm^2/s) and high FA (≥ 0.12) on DTI and presence of cytosolic amino acids (AA, 0.9ppm) , lactate, with/without succinate, acetate, alanine, glycine, and lipid signals on PMRS based on the literature (1, 4). Criteria for the neoplastic cystic lesions identification were high diffusivity (MD $\geq 0.9 \times 10^{-3}$mm^2/s) and low FA (≤ 0.12) on DTI and the presence of lactate/lipids (1.33ppm) and choline (3.2ppm) signals on PMRS.
Statistical analysis was also performed to test the sensitivity and specificity of spectral and DTI parameters obtained from the lesions. Besides this, descriptive statistics by cross-tabulation in all the 53 cases was also done to check the predictability or positivity of the PMRS, MD, and FA indices in describing the nature of lesion (i.e. whether abscess or cystic tumor) and were marked as 'a, b, and c' respectively.

RESULTS: Findings from all the 53 patients are summarized in tables 1 and 2. All the lesions appeared hyperintense on T2- and hypointense on T1-weighted images with perifocal edema and showed rim enhancement on post-contrast T1-weighted images. After combining the results of spectroscopy and DTI, there were 40 cases with brain abscess and 13 cases with tumor cyst other than abscess. Most of the brain abscesses (n=30) had MD values lower than control. All the diagnosed 40 cases of abscess had high FA while all the 13 cases of tumor cysts had high MD values (table 1). Descriptive statistics by cross-tabulation for the entire data set of 53 patients revealed that in group I of abscess, 25 cases fulfilled the diagnostic criteria by all three indices (i.e. a, b, and c); 12 from two indices [(n=7; a and c) and (n=5; b and c)] and remaining 3 by one index (c) only (table 2). In group II of cystic tumors, there were 10 cases fulfilled the diagnostic criteria by all the three indices (a, b, and c) while 3 by two indices (a and b) only. Sensitivity and specificity for the differentiation of brain abscess from cystic tumors for PMRS were 0.8 and 1.0 respectively; for MD these were 0.75 and 1.0 respectively; and for FA, these were 1.0 and 0.76 respectively.

Table 1: Categorization of intracranial lesions based on PMRS, MD, and FA.

Group I, Abscess (n=40)				Group II (Cystic tumors (n=13)			
	PMRS (a)	MD (X 10^{-3} mm^2/s) (b)	FA (c)		PMRS (a)	MD (X 10^{-3} mm^2/s) (b)	FA (c)
(n=25)	AA +	≤ 0.9	≥ 0.12	(n=2)	Cho, L	≥ 0.9	≤ 0.12
(n=7)	AA +	≥ 0.9	≥ 0.12	(n=1)	Cho, L	≥ 0.9	≥ 0.12
(n=3)	AA -	≥ 0.9	≥ 0.12	(n=8)	L	≥ 0.9	≤ 0.12
(n=5)	AA -	≤ 0.9	≥ 0.12	(n=2)	L	≥ 0.9	≥ 0.12

PMRS, proton MR spectroscopy (a); MD, mean diffusivity (b); FA, fractional anisotropy (c), AA, amino acid; Cho, choline; L, lactate; +, present; -, absent.

Table 2: Predictability of PMRS (a), MD (b), and FA (c) for defining the lesions

Intracranial lesions	Predictability			
	3 Indices	2 Indices	1 Index	Total
Abscess	25 (a, b, c)	12 [(n=7; a, c) (n=5; b, c)]	3 (c)	40
Cystic tumors	10 (a, b, c)	3 (a, b)	0	13
		Total		53

DISCUSSION AND CONCLUSION: In the current study we have attempted to classify the cystic intracranial mass lesions based on PMRS and DTI results and have observed that both PMRS and DTI are complementary in its differential diagnosis. Findings indicate that FA measurements are more sensitive (sensitivity, 1) in predicting the abscess; while PMRS and MD indices are more specific for differentiating it from tumors (specificity, 1). It appears that neither PMRS nor DTI indices (MD and FA) are complete in its differentiation; no technique in isolation can predict the actual etiology. We conclude that combining PMRS with DTI helps in better tissue characterization of these cystic intracranial mass lesions

REFERENCES: 1. Mishra AM etal. J Comput Assit Tomog. 2004;28(4):540-547. 2. Kim SH et al. Radiology 1997;204:239-245. 3. Krabbe K et al. Neuroradiology. 1997;39:483-489. 4. Gupta RK et al. (2005). Am J Neuroradiology 26: 1107-1114. 5. Purwar A, et al. Proceedings of ESMRMB, September 21-23, 2006, Abstract #644;