Diagnostic Performance of DTI in Differentiating Glioblastomas from Brain Metastases

Sumei Wang[1], Sang Joon Kim[1,2], John H Woo[1], Suyash Mohan[1], Ruyun Jin[3], Matthew R Voluck[1], Ronald L Wolf[1], Donald M O'Rourke[4], Harish Poptani[1], Elias R Melhem[1,5], and Sungheon Kim[6]

[1]Radiology, University of Pennsylvania, Philadelphia, PA, United States, [2]Radiology, University of Ulsan Asan Medical Center, Seoul, Korea, [3]Medical Data Research Center, Providence Health & Services, Portland, Oregon, United States, [4]Neurosurgery, University of Pennsylvania, Philadelphia, PA, United States, [5]Radiology, University of Maryland, Baltimore, MD, United States, [6]Radiology, New York University School of Medicine, New York, NY, United States

Introduction

The purpose of this study is to evaluate the diagnostic performance of DTI in differentiating brain tumor types. Differentiation between glioblastomas and brain metastasis remains challenging when patients present with a solid enhancing mass as both of them may exhibit ring-enhancement and extensive edema[1-2]. Our previous study showed a feasibility of using DTI metrics to differentiate glioblastomas from metastases with a small cohort (n = 63)[3]. In this study, we further investigated the potential of DTI metrics for differentiation tumor types with a substantially larger cohort (n = 222) and also its performance in comparison with two experienced neuroradiologists.

Materials and Methods

Patients with enhancing lesions (n = 222) were included in this study. Histopathologic analysis of the resected tissue confirmed the diagnosis of glioblastomas in 128 patients (78M/50F, age 24-90) and brain metastasis in 94 patients (46M/48F, age 44-88). Of the 94 metastases, the primary sites for cancer include lung (57), breast (15), melanoma (8), colon (3), renal (2), sarcoma (2), parotid (1), esophageal (2), thyroid (1), peritoneal (1), endometrial (1) and ductal (1). All patients underwent MRI before surgery on a 3T Siemens Tim Trio scanner with a 12-channel phased-array head coil. DTI data was acquired using a single shot; spin echo EPI sequence with parallel imaging using GRAPPA and acceleration factor of 2. 55 patients (40 glioblastomas, 15 metastases) were acquired with 12 diffusion weighting directions (TR/TE = 4900/83, NEX = 6) and remaining 167 patients were acquired with 30 directions (TR/TE = 5000/86, NEX = 3). Other sequence parameters were as follows: FOV = 22 x 22 cm^2, b = 0, 1000 s/mm^2, slice thickness 3 mm. It is assumed that there is no significant difference in MD and fractional anisotropy (FA) between 12 and 30 direction DTI data, as shown in other work[4]. DTI post processing was performed off-line using in-house software. Contrast-enhanced (CE) T1 weighted images, FLAIR, FA and MD maps were coregistered and the tumor was segmented semi-automatically using IDL routines. DTI metrics from the enhancing (ER) and immediate peritumoral regions (IPR) were measured and the best model was determined using multivariate logistic regression analysis as follows[5]:

$$f(MD_{ER}, FA_{ER}, FA_{IPR}) = \frac{1}{1+\exp(-(\beta_0+\beta_1 MD_{ER}+FA_{ER}+\beta_3 FA_{IPR}))}$$

where β_0 = -7.07, β_1 = 1.86, β_2 = 51.77, and β_3 = -8.74. Two faculty neuroradiologists independently reviewed the images based on CE T1, FLAIR, DWI, FA and MD maps. The rating was classified into 5 scales based on the following 5 confidence levels: Level 1, 90% metastasis; 2, 70% metastasis; 3, 50%; 4, 70% glioblastoma; 5, 90% glioblastoma. The Kappa test was performed between the two raters for all the cases. All cases rated as 2, 3 and 4 represent challenging cases for the raters and were grouped together as Indeterminate Group 1, i.e. challenging cases for the raters. Likewise, the cases with the logistic regression model (LRM) output, $f(MD_{ER}, FA_{ER}, FA_{IPR})$, ranging from 0.2 to 0.8 represent challenging cases for LRM such that they were grouped together as Indeterminate Group 2, i.e. challenging cases for the model. ROC curves were generated from each of the raters and LRM for the all cases as well as two sub-groups of indeterminate cases, respectively.

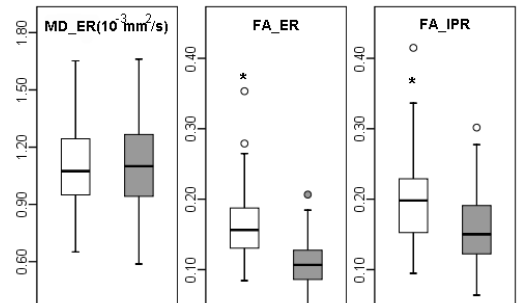

Fig.1 Box plot of FA and MD from the enhancing (ER) and immediate peritumoral region (IPR) in glioblastomas (white) and brain metastases (gray). The outliers are represented by circles. * indicate significant difference ($p<0.01$)

Results

Box plot of FA and MD from the ER and IPR are shown on Fig. 1. The Kappa value between the two raters, Rater 1 and LRM, Rater 2 and LRM were 0.29, 0.16, 0.18 respectively, indicating slight to fair agreement. The LRM had the highest sensitivity whereas Rater 1 had the highest specificity. The AUC values are similar among the raters and the LRM. This result indicates the two raters and the LRM had differences in their confidence levels for individual cases, but in overall the performance of LRM was close to both raters. Seventy two cases were identified as Indeterminate Group 1. For this group of challenging cases, the sensitivity, specificity and AUC of the two raters decreased substantially as shown in Table 1 and Figure 2. In contrast, the performance of the LRM remained about the same level as those with all cases. For the challenging cases with the LRM, 113 cases were identified as Indeterminate Group 2. For this group, both raters performed similarly as they did with all the cases. The accuracy of the LRM decreased mildly as shown by Table 1 and Figure 2.

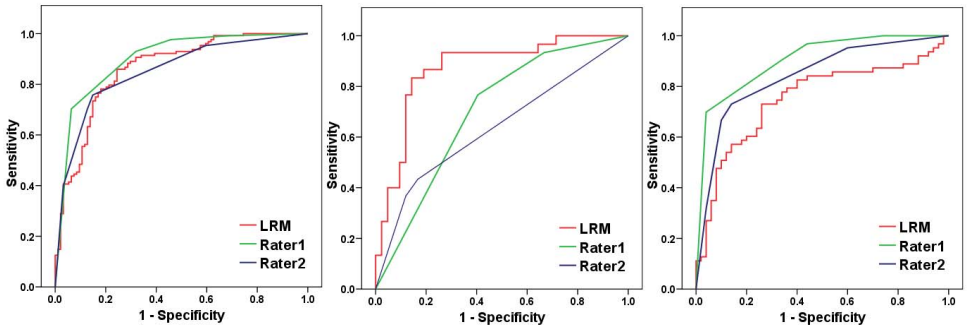

Fig.2 Receiver operative characteristic (ROC) curves from two raters and logistic regression model (LRM) for all cases (left), Indeterminate Group 1 (middle) and Indeterminate Group 2 (right).

Table 1: Sensitivity, specificity and AUC values of the three groups

	All cases			Group 1			Group 2		
	Sensitivity	Specificity	AUC	Sensitivity	Specificity	AUC	Sensitivity	Specificity	AUC
LRM	0.86	0.76	0.862	0.83	0.86	0.871	0.73	0.74	0.751
Rater 1	0.70	0.93	0.900	0.76	0.59	0.700	0.69	0.96	0.903
Rater 2	0.76	0.85	0.853	0.43	0.83	0.638	0.73	0.86	0.841

Discussion

Our prior studies have shown that FA and MD from the enhancing part and immediate peritumoral region are very useful for differentiating glioblastomas from brain metastases[3,5,6]. In this study, the diagnostic performance of LRM was compared with two experienced neuroradiologists. Our result indicates that our model is as good as experienced neuroradiologist. Furthermore, it was found that the accuracy of LRM model did not vary as much as those of the raters depending on the selection of the cases.

Reference

1. Lu S, et al. AJNR 2003;24:937. 2. Tsuchiya K, et al. Br J Radiol 2005;78:533. 3. Wang S, et al. Neuroimage 2009; 44:653.
4. Landman BA, et al. Neuroimage 2007;36:1123. 5. Wang S, et al. Proceeding of ISMRM 2012. 6. Wang S, et al. AJNR 2011;32:507.