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ORIGINAL ARTICLE

Differentiation between high-grade gliomas and metastatic brain tumors using Diffusion Tensor Imaging metrics

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KEYWORDS

DTI;
Brain tumors;
MRI;
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Abstract *Introduction:* The aim of this work was to differentiate between high-grade gliomas and metastatic brain tumors using diffusion tensor derived metrics in the enhancing tumor and peri-tumoral regions.

Patients & methods: Prospective study was done on 36 patients with provisional MRI diagnosis of high grade gliomas WHO grade III & IV versus metastatic brain tumors, examination was done on 1.5 tesla scanner, patients were divided into two groups based on pathology results, the fraction anisotropy (FA), mean diffusivity (MD), linear coefficient (CL), planer coefficient (CP) and spherical coefficient (CS) were measured in the enhancing tumor parts and immediate peri-tumoral edema and results were compared between the two groups.

Results: Values of FA, CL and CP measured in the peri-tumoral edema were significantly high in the metastatic than primary high malignant glial tumors with high specificity (100%) of the CP and high sensitivity of the CL (76.5%) among the three significant values, and no significant differences in the values of MD and CS. The values of the five metrics measured in the enhancing tumor parts showed no significant differences between the two groups.

Conclusion: Brain metastasis and high-grade gliomas can be differentiated using DTI derived FA, CL and CP measured in the peri-tumoral region.

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1. Introduction

According to WHO 2007 classification glioblastoma and brain metastases are the most common brain neoplasms in adults (1), and the radiological and clinical differentiation between

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these two neoplasms is very important to achieve good clinical outcome as they have different management strategies (2). In conventional MRI both neoplasms are of often similar in single lesion appearance as they both have similar necrotic center, irregular enhancing margin and surrounding edema (3). The clinical data of primary extra cranial neoplasm and the radiological appearance of intracranial multiplicity favoring the diagnosis of metastases, a solitary brain metastasis may be the first manifestation of disease in about 30% of patients with systemic cancer (4). So, the appearance of the solitary brain metastases on magnetic resonance imaging (MRI) can be nonspecific. Although glioblastomas typically present as a solitary mass, glioblastomas can occasionally present as multiple marginally enhancing lesions. Hence, accurate distinction between glioblastomas and brain metastases remains challenging, which often necessitates an invasive surgical biopsy for a definitive diagnosis (5).

Diffusion MRI was used in the evaluation of different types of malignancies years ago (6,7), and the diffusion tensor imaging (DTI) has been increasingly used to study pathologic changes in brain tumors (8,9). DTI has also been investigated in differentiating glioblastomas from metastases (10–12). Different diffusion tensor metrics were used as a quantitate analysis of the different types of glial and metastatic brain tumors, and the most common used are fraction anisotropy (FA), and mean diffusivity (MD) which equals the apparent diffusion coefficient (ADC).

MD reveals the rate of the water molecules diffusional motion. Tumor cellularity is the main target of histologic tumor classification with DTI. There is inverse relationship between the tumor cellularity (intracellular space) and the MD value, and the decrease in water diffusivity is explained by a relative decrease in extracellular space available to move water molecules (13,14). This inverse correlation has been reported in glial (9) and non-glial tumors (15).

FA expresses orientation of tissue microstructure, so its use is beyond the white matter tracts characterization (13). FA is related to structural orientation of different tissues not only white matter as demonstrated by high anisotropy values reported in brain abscesses (16), glioblastomas (17) and areas of hemorrhage (16). The relationship between FA and tumor cellularity is unclear, as both positive (17,18) and negative (19) correlation has been reported. While FA is a good indicator of diffusion anisotropy, it does not provide information on the shape of the diffusion ellipsoid as it cannot distinguish a flat ellipsoid from an oblong one.

Westin et al. (20) have derived a set of three basic metrics that modeled diffusion anisotropy that expresses the shape of the diffusion tensor: linear anisotropy coefficient (CL) where diffusion is mainly along the direction corresponding to the largest eigenvalue; planar anisotropy coefficient (CP) where diffusion is restricted to the plane spanned by the two eigenvectors with the two largest eigenvalues; and spherical anisotropy coefficient (CS), which indicates isotropic diffusion.

Each anisotropy coefficient shows unique measure in different areas of WM. These differences are due to the impact of the linear, planar, and spherical shape components of the tensor. Linear ellipsoid is seen in regions with parallel-arranged white matter tracts, such as great tracts of the corpus callosum and corticospinal tract. Planar ellipsoid corresponds to regions of fibers with different orientations, or bundles of fibers that randomly oriented in a plane, as centrum semiovale and subcortical white matter regions. The gray matter appears isotropic with high CS (21).

2. Patients

The local ethics committee approved this prospective study and full written consents were obtained from all patients prior to the examination. The study included 36 patients provisionally diagnosed to have intra-axial high-grade gliomas or brain metastatic deposits based on conventional MRI. Only patients with final histopathological diagnosis after surgery or biopsy were included. Patients with previous cranial operation or radiotherapy and patients without histopathological diagnosis were excluded. Patients with known hypersensitivity to the contrast medium and contraindications for MRI (peacemakers – head and neck metallic prosthesis, etc.) were also excluded. All patients were referred from neurosurgery department to MRI neuroimaging unit at Mansoura University Hospitals in the duration between January 2013 and January 2015.

Based on histopathological results patients were divided into two groups: group 1 with primary high-grade gliomas including 19 patients and group 2 with metastatic brain tumors including 17 patients.

3. MRI

3.1. Technique

The MR imaging was performed using a 1.5 tesla scanner (Ingenia, Philips) using dStream HeadNeck 20 channel coil, firstly noncontrast study was done, the T1 (TR/TE,620/20 ms), T2 (TR/TE,5430/95 ms) and FLAIR (TR/TE/TI, 10500/120/2800 ms) sequences with matrix 80×80, FOV 230×177 mm^2 and slice thickness about 5 mm were obtained, then post-IV-contrast T1 image study was done using gadoterate meglumine, and 0.5 mL/kg (0.1 mmol/kg) body weight with maximum dose of 10 mL was administrated (using 20 to 22 G venous cannula) as an intravenous bolus injection at a flow rate of approximately 2 mL/s.

3.2. Diffusion tensor imaging (DTI)

DTI data were obtained using a single-shot echo planar imaging sequence (TR/TE 3118/93 ms) with parallel imaging (SENSitivity Encoding [SENSE] reduction factor P 2). Diffusion gradients were applied along 32 axes, using a *b*-value of 0 and 1000 s/mm^2. A field of view (FOV) of 224×224 mm^2 and a data matrix of 92×88 were used, leading to voxel dimensions ($2.43 \times 2.54 \times 2.5$ mm^3). Forty-eight slices were obtained, with a thickness of 2.5 mm, with no gap, and with the total scan duration of about 7–8 min.

3.3. Postprocessing

The DICOM images were transferred to workstation (extended MR Workspace 2.6.3.5, Philips medical systems Nederland BV), firstly automated registration of the DTI data was done to eliminate eddy current artifacts, then fiber tracking advanced tools started.

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