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Role of diffusion tensor imaging metrics and in vivo proton magnetic resonance spectroscopy in the differential diagnosis of cystic intracranial mass lesions☆

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Abstract

The purpose of this study was to determine whether proton magnetic resonance spectroscopy (PMRS) and diffusion tensor imaging (DTI) indices, fractional anisotropy (FA) and mean diffusivity (MD) can be used to distinguish brain abscess from cystic brain tumors, which are difficult to distinguish by conventional magnetic resonance imaging (MRI). Fifty-three patients with intracranial cystic mass lesions and 10 normal controls were studied. Conventional MRI, PMRS and DTI of all the patients were performed on a 1.5-T GE scanner. Forty patients were with brain abscess and 13 with cystic tumors. Cytosolic amino acids (AAs) were present in 32 of 40 brain abscess patients. Out of 13 patients with cystic tumors, lactate and choline were seen in 3 and only lactate was present in 10 patients on PMRS. All 40 cases of abscess had high FA, while all 13 cases of tumor cysts had high MD values. We conclude that FA measurements are more sensitive in predicting the abscess, while PMRS and MD are more specific in differentiating abscess from cystic tumors. We suggest that PMRS should be combined with DTI rather than with diffusion-weighted imaging as FA can be used as an additional parameter for separation of abscess from other cystic intracranial mass lesions.

Keywords: Proton magnetic resonance spectroscopy; Diffusion tensor imaging; Fractional anisotropy; Mean diffusivity; Brain abscess

1. Introduction

Intracranial cystic mass lesions appear similar on conventional magnetic resonance imaging (MRI) and show rim enhancement on post-contrast T1-weighted images. Differential diagnosis of these lesions is imperative as the management varies from merely needle aspiration as in brain abscess to surgical excision in cystic neoplasm. A number of studies using either proton magnetic resonance spectroscopy (PMRS) or diffusion-weighted imaging (DWI) or a combination of these two techniques have shown improvement in the differential diagnosis of these lesions [1–5]. The presence of amino acids (AAs) along with lactate, acetate and succinate on PMRS has been considered as the signature of the brain abscess. However, the brain abscess secondary to *Staphylococcus aureus* is known to show dominance of lipids and lactate in animal models as well as in humans and resemble with spectra of glioblastoma multiforme [3,6]. Presence of lactate and choline in cystic lesions is considered as a signature of neoplasm [4]. Brain abscesses usually show restricted diffusion on DWI, a feature characteristic of an abscess, while cystic tumors show high apparent diffusion

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coefficient [5]. However, recently it has been shown that there may not be a restriction of diffusion in the brain abscess and this may cause problems in separating abscess from cystic neoplasm [3].

Diffusion tensor imaging (DTI) is a novel MR technique and has been used in the evaluation of various physiological and pathological processes. The two commonly employed DTI-derived metrics are fractional anisotropy (FA) and mean diffusivity (MD). This technique has been primarily applied in understanding the white matter pathologies which are not detectable with the conventional MRI [7]. Recently, it has shown applications in non–white matter conditions like cortical maturation, brain abscess, hemorrhagic lesions and epidermoids [8–11]. Recently, FA values in the brain abscess cavity have been reported to be similar to the major white matter tracts and are shown to reflect the up-regulation of various adhesion molecules on inflammatory cells that confers the structured orientation of these cells in the abscess cavity [12]. However, no correlation was observed between MD and FA values in the abscess cavity [9].

Combined DTI and PMRS have been used in schizophrenia [13], actinomycotic infection [14], neonatal encephalopathy [15], gliomas [16], amyotrophic lateral sclerosis [17], X-linked adrenoleukodystrophy [18] and fulminant hepatic failure [19]. In the present study, we have prospectively evaluated 53 patients with different cystic intracranial mass lesions using PMRS and DTI. As FA is shown to represent the adherent inflammatory cells while MD represents the viable inflammatory cell density in the brain abscess cavity [12], it would be worthwhile to see the PMRS, FA and MD measures independently or in combination in the differential diagnosis of these cystic intracranial mass lesions.

2. Materials and methods

Fifty-three patients with intracranial cystic mass lesions (30 females and 23 males, mean age=27 years, range=20–35 years) were evaluated in the last 2 years with conventional MRI, PMRS and DTI after their clinical assessment. Ten age- and sex-matched (6 females and 4 males, mean age=26 years, range=21–32 years) healthy controls were also included in the study for the purpose of comparison. The lesions appearing hyperintense on T2-weighted and hypointense on T1-weighted and showing rim enhancement on post-contrast T1-weighted MRI were included in this study. Diagnosis was confirmed by pus aspiration and its culture in brain abscess patients, while it was based on the histopathology in patients with cystic neoplasm. On histopathology, these cystic tumors were Grade I astrocytoma (n=4), Grade II astrocytoma (n=6) and Grade III astrocytoma (n=3). Informed consent was obtained from all the patients or nearest kin of the patient. Ethical approval was also taken from the institutional review board for performing the study on human subjects.

2.1. MRI Protocol

Conventional MRI, PMRS and DTI were performed on a 1.5-T MRI scanner (General Electric Medical System, Milwaukee, WI, USA) using a standard quadrature birdcage receive-and-transmit radiofrequency head coil. The conventional MRI protocol included T2-weighted fast spin echo images with repetition time (TR) (ms)/echo time (TE) (ms)/echo train length/no. of excitations (NEX)=6000/85/16/4 and spin echo (SE) T1-weighted images with TR/TE/NEX=1000/14/2. Both T1- and T2-weighted images were acquired from contiguous (interleaved), 3-mm-thick axial sections with 240×240 mm field of view (FOV) and image matrix of 256×256. Post-contrast T1-weighted images were acquired after intravenous injection of gadolinium diethylenetriaminepenta–acetic acid–bismethylamide (Omniscan, Amersham Health, Oslo, Norway) at a dose of 0.1 mmol/kg body weight.

2.2. In vivo PMRS

In vivo PMRS was performed in all the 53 patients, and spectra were obtained by using position resolved spectroscopy, water-suppressed localized single voxel SE sequence with TR/TE/NEX=3000 ms/144 ms/8. Voxel was placed within the core of the lesion and its size was guided by the lesion size. After global shimming, voxel shimming was performed, and a full width at half maximum of 4–6 Hz was achieved in all the patients. All the spectra were evaluated by an expert radiologist independently using a standard Java-based version of a magnetic resonance user interface signal processing software [20]. On PMRS, the criteria for abscess diagnosis were the presence of cytosolic AAs (0.9 ppm), lactate, with/without succinate, acetate, alanine, glycine and lipid signals [1,3], and for the neoplastic cystic lesions were the presence of lactate along with choline or lactate only [1,3]. Lactate at 1.33 ppm was used as an internal reference of the identification of other visible resonances [21,22].

2.3. DTI Protocol

DTI data were acquired using a single-shot echo-planar dual SE sequence with ramp sampling [23]. A balanced rotationally invariant dodecahedral diffusion encoding scheme with 10 uniformly distributed directions over the unit sphere was used for obtaining the diffusion-weighted and encoded data [24,25]. The b-factor was set to 0 s/mm^2, 1000 s/mm^2, TR=8 s, TE=100 ms. A total of 34–36 axial slices were acquired with an image matrix of 256×256 (following zero-filling), slice thickness of 3 mm with no inter-slice gap and a FOV of 240×240 mm^2. To enhance the signal-to-noise (SNR) ratio and reduce the phase fluctuations, magnitude-constructed images were repeated (NEX=8) and temporally averaged. Total DTI image