ORIGINAL ARTICLE

Discrimination of Brain Abscess and Necrotic Brain Tumor with Proton MR Spectroscopy and Diffusion-Weighted Imaging

Hammad Ahmad Saqib[1*], Aisha Asghar[2], Atqa Firdous[3], Mahwish Zahra[4], Zia Ul Islam[3], Samreen Mushtaq[5]

ABSTRACT

Objective: To compare the efficacy of MR spectroscopy and diffusion-weighted imaging in discriminating between cystic or necrotic tumors and pyogenic brain abscesses.

Study Design: A retrospective study design.

Place and Duration of Study: The Study was conducted at the Radiology Department of Nishtar Hospital Multan and General Hospital Lahore, Pakistan, from January 2022 to January 2023.

Methods: A total ten patients were included in the study. Of 10 patients, 5 had pyogenic abscesses, and 5 had tumors. Tumors were metastases (2 patients), glioblastomas (2 patients), and anaplastic astrocytoma (1 patient). Proton MR spectroscopy and diffusion-weighted imaging were performed in all patients.

Results: Results showed that significant resonance lines (creatine/phosphocreatine, *N-acetyl aspartate,* and choline) observed in normal brain parenchyma were missing in abscesses or necrosis. MR spectroscopy of abscess showed multiple resonance peaks. Diffusion-weighted images showed that all pyogenic abscesses had lower ADC values and were hyperintense compared to normal brains.

Conclusion: Diffusion-weighted imaging is more accurate and less time consuming method for discrimination of brain lesions compared to MR spectroscopy.

Keywords: *Brain Abscess, Diffusion Weighted Imaging, MR Spectroscopy, Tumor.*

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[1]*Department of Radiology*
Ch Pervaiz Elahi Institute of Cardiology (CPEIC), Multan, Pakistan
[2]*Department of Radiology*
General Hospital, Lahore, Pakistan
[3]*Department of Radiology*
Multan Medical and Dental College, Multan, Pakistan
[4]*Department of Radiology*
Children's Hospital and The Institute of Child Health, Multan, Pakistan
[5]*Department of Radiology*
Nishtar Medical University and Hospital, Multan, Pakistan

Correspondence:
Dr. Hammad Ahmad Saqib
Assistant Professor, Radiology
Ch Pervaiz Elahi Institute of Cardiology (CPEIC)
Multan, Pakistan
E-mail: drshafiq33@yahoo.com

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Introduction

It may be challenging to differentiate between brain abscesses and necrotic or cystic tumors through MR or CT imaging. Intracranial abscesses are difficult to diagnose mainly because of a combination of similarity in the morphology of intracranial lesions like cysts, brain abscesses, gliomas, and metastases, and unspecific clinical findings.[1,2] Results of many studies suggest that proton MR spectroscopy (^{1}H-MRS) is a non-invasive tool that may assist in establishing differential diagnosis of brain abscesses and tumors.[3-5]

Diffusion-weighted imaging is a method for evaluating diffusion characteristics of water molecules present in tissues and is used in patients having white matter disorders, epilepsy, tumors, and ischemia.[6] Studies show that diffusion-weighted imaging may provide valuable information about differential diagnosis of cystic necrotic tumors and abscesses.[7,8] In this study, we will compare the efficacy of ^{1}H-MRS and diffusion weighted imaging in discriminating between cystic or necrotic tumors and pyogenic brain abscesses.

Methods

The retrospective study was conducted in Department of Radiology of Nishtar Hospital Multan and General Hospital Lahore, Pakistan from January 2022 to January 2023 after the approval from the Institutional Ethical Review Committee of Ch Pervaiz Elahi Institute of Cardiology (CPEIC), Multan, Pakistan held on December 15, 2021 vide letter no ERC No. 14-51. The study included patients aged between 26-74 years who had necrotic lesion and ring shaped mass detected on MR imaging. Patients younger than 26 years were excluded. Informed consent of the participants was taken. Ethical board of the hospital approved the study.

Of 10 patients, 5 had pyogenic abscesses and 5 had tumors. Tumors were metastases (2 patients), glioblastomas (2 patients) and anaplastic astrocytoma (1 patients). All patients underwent histologic studies and stereotactic or surgical biopsies. Bacteriologic analysis was performed for abscesses. None of the lesions were hemorrhagic.

All proton MR spectroscopy studies were performed through 1.5 T system. The imaging studies included T1 and T2 weighted spin echo and fast fluid attenuated inversion recovery sequences. Voxels were located using T1 or T2 weighted imaging. The voxel position was estimated by visual examination of MR images in 3 orthogonal planes. Point resolved spectroscopy was used for applying ^{1}H-MRS. In 4 patients, phase inversion associated with lactate, alanine and amino acid was confirmed by obtaining additional MR spectra. It was used to discriminate lipid signals from amino acid or lactate signals.

Spectroscopy analysis package was used to transfer ^{1}H-MRS data offline for post processing. Metabolites were assigned resonance peaks on the basis of previous literature.[9] Resonance peaks were either low (+), medium (++) or high grade (+++).

Diffusion weighted imaging was done after ^{1}H-MRS. Three sets of images were obtained by applying diffusion gradients in 3 orthogonal planes. Signal intensity of necrotic or cystic portion of diffusion weighed images was visually characterized into markedly low, slightly low, slightly highly and markedly high as compared to normal parenchyma.

Diffusion changes were analyzed by calculating apparent diffusion coefficient (ADC) on the basis of Stejskal and Tanner equation.[10] SPSS version 23.0 was used for analyzing diffusion weighted imaging. Inter case comparison was done by computing ratio of ADC of the lesion to that of control region.

Results

All spectra were analyzable except in 2 patients, who had nonspecific diagnosis due to poor shimming or contamination from surrounding fat (Figure 1). Table I shows patient characteristics based on diffusion weighted imaging and ^{1}H-MRS findings. Major resonance lines (creatine/phosphocreatine, *N*-acetylaspartate and choline) observed in normal brain parenchyma were missing in both abscesses and tumoral necrosis. ^{1}H-MRS of abscess showed multiple resonance peaks. In 2 patients with abscesses, major finding were resonances of lactate (1.3ppm), alanine (1.5ppm), acetate (1.9ppm), and amino acids (valine, leucine, and isoleucine) (.9ppm) (Figure 2). In 1 patient, succinate peak was detected. In only 1 patient, who developed abscess after 35 days of antibiotic treatment, resonance lipid and lactate were found. (Figure 3).

In 2 patients with necrotic or cystic tumor, spectra showed lactate peak. In 2 tumor patients' lipid and lactate were found. Diffusion weighted images showed that all pyogenic abscesses had lower ADC values and were hyperintense compared to normal brain. The ADC ratio and ADC value were 0.66 and $0.68 \pm 0.16 \times 10^{-3}$ mm^2/s respectively. The diffusion weighted image of necrotic and cystic area showed that tumors were hypointense, and their necrotic or cystic areas had higher ADC value. ADC value for cerebrospinal fluid was $3.64 \pm 0.31 \times 10^{-3}$ mm^2/s. ADC value for white and gray matter were $0.9 \pm 0.14 \times 10^{-3}$ mm^2/s and $0.86 \pm 0.14 \times 10^{-3}$ mm^2/s respectively (Table 1).

Discussion

Brain abscess are diagnosed on the basis of clinical examination and neuroimaging (e.g. MR and CT imaging findings). Some necrotic or cystic tumors have similar neuroimaging appearance as of brain abscess. Brain abscesses and tumors are managed

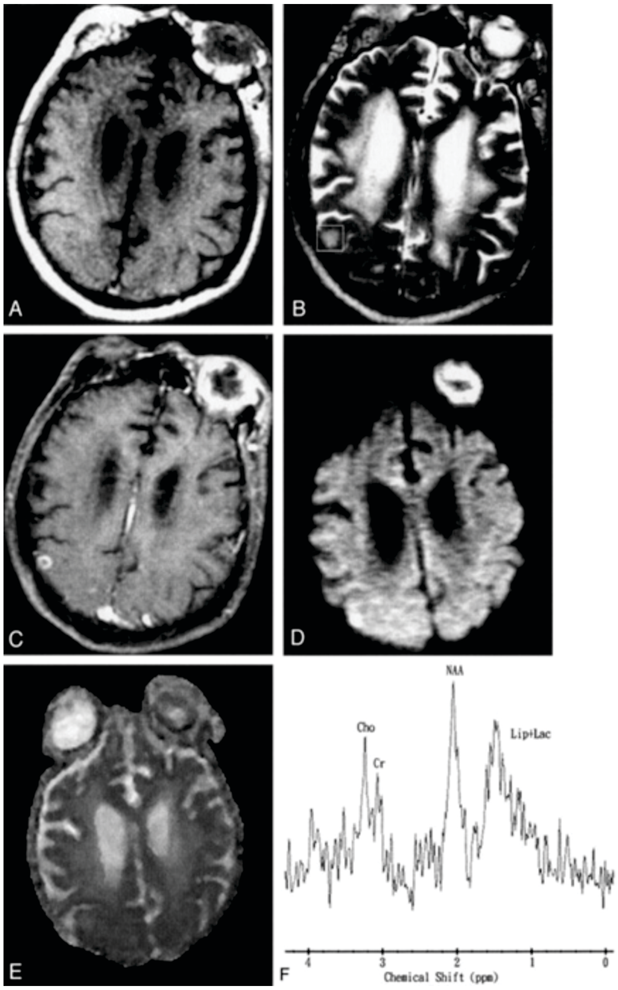

Fig 1: Image of patient with *Klebsiella pneumoniae* bacteremia, endophthalmitis of left eye, renal and brain abscess

A Axial T1 weighted image

B Axial T2 weighted image

C Axial T1 weighted image with contrast

D Axial diffusion weighted image

E ADC map

F In vivo ^{1}H-MR spectrum unacceptable due to small lesion and contamination from surrounding fat.

through different medical strategies. It is important to correctly diagnose both before beginning treatment. Diffusion weighted imaging and ^{1}H-MRS are valuable for discriminating between brain abscess and necrotic or cystic tumors. In this study we compared efficacy of ^{1}H-MRS and diffusion weighted imaging in discriminating between both. In our study, all abscesses and cystic tumors showed increased lactate, which is the byproduct of anaerobic glycolysis.[4] All necrotic and cystic tumors

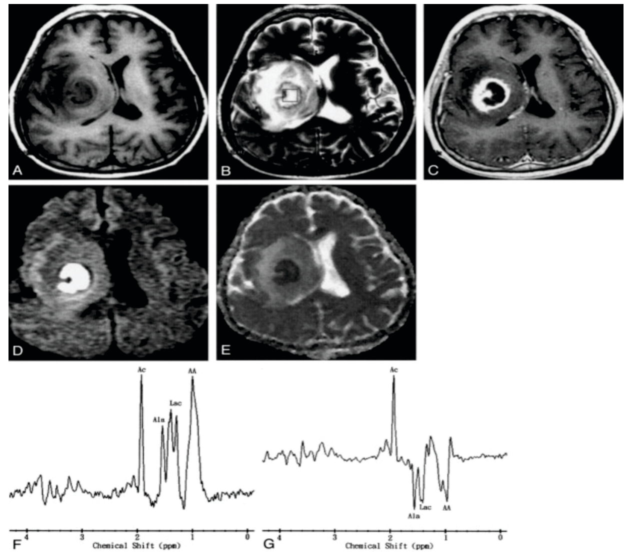

Fig 2: Image of patient with pyogenic brain abscess

A Axial T1weighted image

B Axial T2 weighted image

C Axial T1weighted image with contrast

D Axial diffusion weighted image

E ADC map

F, G In vivo ^{1}H spectra shows resonance of acetate, alanine, lactate and amino acids

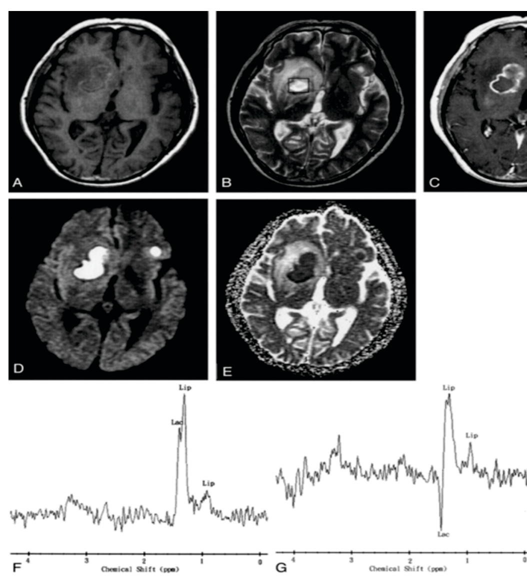

Fig 3: Case with antibiotic treatment started 35 days before imaging

A Axial T1 weighted image

B Axial T2 weighted image

C Axial T1-weighted image with contrast

D Axial diffusion weighted image

E ADC map

F, G In vivo ^{1}H spectra shows lipid peak (0.8–1.2 ppm) and lactate peak (1.3 ppm)

Table 1: Findings of diffusion weighted imaging and ^{1}H-MRS in study population

Patient	Diagnosis	Metabolites Detected	Signal Intensity on Diffusion Weighted Image
1	Brain abscess	Ace(+++), Ala(++), AA(+++), Lac(+++)	Markedly high
2	Brain abscess	Ace(+++), Succ(++), Ala(++), AA(++), Lac(++), NAA(+), Cho(+), Cr/PCr(+)	Markedly high
3	Brain abscess	Ace(+++), Ala(++), AA(+), Lac(++)	Markedly high
4	Brain abscess	Ace(+++), Ala(++), AA(+), Lip(+), Lac(++)	Markedly high
5	Brain abscess	*	Markedly high
6	Glioblastoma	Lac(++), NAA(+), Cho(+++), Cr/PCr(+)	Markedly low
7	Glioblastoma	Lip(+), Lac(++)	Slightly low
8	Anaplastic astrocytoma	Lac(+++), NAA(+), Cho(+++), Cr/PCr(+)	Markedly low
9	Metastatic brain tumor	Lip(+), Lac(++)	Markedly low
10	Metastatic brain tumor	Lip(+), Lac(++), NAA(+), Cho(+++), Cr/PCr(+)	Markedly low

**Resonance peaks: low (+), medium (++) or high grade (+++)*

except 3 (2 metastases and 1 glioblastoma) had lactate signals of varying peak height. In 3 cases lipid and lactate signals were seen. and in two cases of tumors, lipid and lactate signals were found. The spectrum of 1 patient with abscess cavity had specific finding showing elevation of amino acid, succinate, acetate and lactate. This spectrum was significantly different from that of necrotic or cystic tumor. Our findings are consistent with results of previous studies.[4,11] Increase in succinate, acetate and lactate is due to increased glycolysis and fermentation of infectious microorganisms. Amino acids like leucine and valine are released after proteolysis by enzymes in pus.

It is important to discriminate between lipid (at 0.8–1.2 ppm) and amino acid acids (i.e. isoleucine, valine and leucin at .9 ppm) as lipid signal may be present in both abscesses and tumors, while amino acids can only be detected in vitro proton MR spectra of tumors, not in vivo. ^{1}H-MRS findings of the patients before initiating antibiotic therapy or 1 patient who had antibiotic for two days showed spectrum specific to the brain abscess, which has also been reported by the previous study.[12] However, ^{1}H-MRS could not show all specific metabolites in patient who was treated with antibiotics for 35 days before the examination. Lactate and lipid peak in this patient was nonspecific. It shows that ^{1}H-MRS has spectral specificity for untreated cases only. Though, small number of cases were analysed in our study, our findings are supported by a previous study which reported that pyruvate and acetate decrease after a week of aspiration or medical treatment so are not detectable on ^{1}H-MRS.[13] They suggested that absence of these metabolites imply positive response to treatment. It was observed that ^{1}H-MRS examination abscess after 29 and 112 days of antibiotic therapy showed dramatic findings. All resonances (for amino acids, alanine, acetate, succinate) except lactate disappeared. These spectral changes imply effective therapy, as shown in our and previous studies, and emphasizes that fact that spectroscopist or neuro radiologist should be aware of patient history. The ^{1}H-MRS examinations should be preferably performed before start of therapy.

Previous studies have shown that diffusion weighted imaging can effectively distinguish between brain abscesses and tumors.[14,15] A study reported that diffusion weighted imaging of brain abscess shows high spectral intensity. The consistency of pus cause restricted diffusion and result in high signal intensity of diffusion weighted imaging.[2] In our study, the findings of pyogenic abscesses were in line was those reported by previous study.[8] Diffusion weighted imaging even reported high signal intensity in patient who was treated for 35 days before the imaging. ADC ratios for pyogenic abscesses ranged from 0.45-0.7, this variability can be due to different concentrations of bacteria, viscosity of fluid and necrotic tissue debris. There are little doubts about identification of necrotic or cystic tumors, diffusion weighted images of necrotic or cystic parts of tumor had low signal intensity and high ADC value. However, there are contrasting findings. A previous study showed that two cases of necrotic or cystic brain tumor had high signal intensity. Surgery revealed thick pus like necrotic content of the cyst.[7] Another study reported that diffusion weighted imaging of necrotic tumor showed ring enhanced metastasis having hyperintensity and low ADC value.[16] Though, sample size in current study is small, result showed that diffusion weighted imaging was more accurate and practical compared to ^{1}H-MRS.There are several reasons to believe this. First diffusion weighted imaging is less time consuming. Second, compared to diffusion weighted imaging single-voxel ^{1}H-MRS has limited voxel size which affects view of smaller lesion. Third, diffusion weighted image of a case of pyogenic abscess showed hyperintensity, while ^{1}H-MRS examination showed lactate lipid peaks only, which is similar to the spectrum of a case of necrotic tumor. The limitation of this study is design and small sample size, larger prospective studies are recommended for thorough evaluation of specific spectral peaks and assessment of the course of spectral changes after antibiotic treatment.

Conclusion

Diffusion weighted imaging is more accurate and less time consuming modality for discrimination of brain abscess and necrotic brain tumor compared to ^{1}H-MRS, which is more limited in case of treated abscesses and smaller lesions.

Authors Contribution

HAS: Study designing, data analysis, results and interpretation

AA: Idea conception and data collection

AF: Data collection, manuscript writing and proof reading

MZ: Study designing, data analysis, results and interpretation

ZUI: Data collection, data analysis, results and interpretation

SM: Data collection, manuscript writing and proof reading

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