|| Print ISSN: 2589-7837 || Online ISSN: 2581-3935 ||
International Journal of Medical Science and Diagnosis Research (IJMSDR)
Available Online at www.ijmsdr.com
PubMed (National Library of Medicine ID: 101738824)
Volume 3, Issue 12; December: 2019; Page No. 08-15
Original Research Article
crossref DOI: https://dx.doi.org/10.32553/IJMSDR/v3i12.3

# ROLE OF MAGNETIC RESONANCE SPECTROSCOPY AND DIFFUSION WEIGHTED IMAGING IN DISCRIMINATION BETWEEN BRAIN ABSCESS AND NECROTIC BRAIN TUMORS

**Kailash Prajapat[1], Rajkumar Yadav[2], Naima Mannan[3], Usha Jaipal[4], Meenu Bagarhatta[5], Kuldeep Mendiratta[6], Himanshu Sharma[7].**

[1] Post Graduate Student, [2]Associate Professor, [3]Senior Professor, [4] Senior Professor, [5]Senior Professor & Head, [6] Senior Professor, [7] Consultant Radiologist.

[1-6] Department of Radiodiagnosis and Modern Imaging, SMS Medical College, RUHS, Jaipur.

[7] Consultant Radiologist, Jaipur.

Conflicts of Interest: Nil

Corresponding author: Rajkumar Yadav

**Abstract:**

**Aim**: The present study was conducted to determine role of MRS and DWI in differentiating brain abscesses from necrotic brain tumors with the following objectives:

1. To determine signal intensity, diffusion motion of content & ADC values in patients with brain abscess and necrotic brain tumors.
2. To determine assignment of various resonances of chemical component on MRS.

**Material & Methods**: Descriptive type of observational study conducted in the department of Radio-diagnosis and Modern Imaging, Neurology, Neurosurgery of SMS Hospital Jaipur, Rajasthan. A sample size of 64 subjects for each of two groups at Alpha error 0.05 and power 80% assuming area under ROC 0.7 between Diagnostivity for brain abscess and brain tumor. So for study purpose 64 brain abscess cases and 64 necrotizing brain tumor cases were taken .All patient underwent MRI examination which was performed on PHILIPS INGENIA 3 TESLA MRI. Diffusion weighted Imaging with MRS sequences were taken along with conventional MRI sequences. Validation of MRI findings was done through Histology and/or Follow up. Continuous variables were summarized as mean and standard deviation while nominal/categorical variables as proportions(%).Statistical analysis was applied to find out the Sensitivity, Specificity, PPV, NPV and Accuracy of MRI to discriminate brain abscesses with necrotic brain tumors. P-value < 0.05 was taken as significant.

**Results**: DWI with MRS was 87.5% Sensitive and 100% Specific in differentiation between brain abscesses and necrotic/cystic brain tumors. The Positive and Negative predictive values and over all Accuracy of MRS and Diffusion WI was 100%, 88.9% and 93.7% respectively.

**Conclusion**: Spectroscopic and Diffusion weighted MRI are advanced MR techniques that are used to add important physiological and metabolic information to that obtained with conventional MRI and are fast, easy to perform, non-invasive, and provide additional information that can accurately differentiate between necrotic/cystic brain tumors and cerebral abscesses.

**Keywords**: Brain Abscess, Necrotic Brain Tumor, DWI, MRS.

## Introduction

Brain abscess and tumors are universal health problem with a high morbidity and mortality rate; thus the disease presents a leading public health problem and burden on health care facilities all around world. The annual incidence of brain abscess is 1.88 and brain tumor is 10-17 per 1,00,000 persons (1)

Attempts to differentiate brain abscesses from necrotic tumors at conventional magnetic resonance imaging have met with little success because the presenting clinical manifestations & neuroradiological findings are often non specific (1,2) Only 40-50% of patients with brain abscess are febrile on examination and more common signs are those of expanding intracranial mass like headache, focal sensorimotor deficits, seizure, nausea & vomiting (3,4)

On Conventional MRI, the abscess centre usually shows hypointensity to the brain parenchyma on T1 weighted images & hyperintensity on T2 weighted images. The abscess wall usually shows a ring of enhancement after contrast administration. Although marked hypointensity of abscess capsule as seen on T2 weighted image is characteristic of brain abscess, the hypointense capsule is not always seen in all abscesses & may be seen in some cases of brain tumor (5)

Diffusion weighted imaging (DWI) provides a useful tool to evaluate the diffusion properties of water molecule in tissue. A marked difference in the signal intensity on DWI between brain abscess & necrotic tumors may be due to different physical & biological components of the central contents. Abscess likely to shows restricted diffusion in DWI with low ADC (apparent diffusion coefficient) due to highly viscous content, while the necrotic tumor cavity more likely to shows free diffusion with high ADC value due to clear serous fluid (2).

MR SPECTROSCOPY from brain abscesses show the assignment of various resonances of acetate (Ac), alanine (Ala), lactate (Lac) and amino acids (AA) (6, 7). MRS of necrotizing brain tumors, voxels in the centre necrotizing part shows mainly increase lactate peak especially at short TE(echo time) sequence of 144 (8).

The medical management strategies for abscess and neoplasms are different, correct diagnosis must be obtained before the treatment of cystic brain lesions (9), knowledge of the exact nature of the lesion helps neurosurgeon to determine the best management. For example, cerebral abscess can be stereotactically aspirated, followed by intravenous antibiotic therapy hence avoiding craniotomy (10).

Diffusion weighted imaging (DWI) and magnetic resonance spectroscopy (MRS) shown to light the blind spots of conventional MRI with a significant increase in diagnostic accuracy when used as an adjunct (9, 11).

Combined use of MRS and DWI may improve results compared with the use of a single technique to differentiate brain abscess from cystic tumor. MRS and DWI are complement to conventional MRI for better characterization of intracranial cystic brain lesions (12).Thus present study was conducted to determine role of MRS with DWI in differentiating brain abscesses from necrotic brain tumors.

## MATERIAL AND METHODS

Descriptive type of observational study conducted in the department of Neurology, Neurosurgery & Radiodiagnosis and Modern Imaging, SMS Hospital Jaipur, Rajasthan. A sample size of 64 subjects for each of two groups at Alpha error 0.05 and power 80% assuming area under ROC 0.7 between diagnostivity for brain abscess and brain tumor. So for study purpose 64 brain abscess cases and 64 necrotizing brain tumor cases were taken.

**INCLUSION CRITERIA:-**

1. All patients with complaints suspicious of brain abscess or brain tumors.
2. All patients in whom the conventional MRI features were suggestive of necrotic marginally enhanced lesion in the brain.

**EXCLUSION CRITERIA:-**

1. Patients who were previously operated for intracranial tumor or abscess.
2. Patient having received radiation therapy for intracranial tumor.
3. Patient with solid brain tumors.
4. Patients unfit to undergo MRI like metallic aneurysms clips, pacemakers, metallic vascular clamp placement, history of claustrophobia.

Patient selected after applying inclusion & exclusion criteria. Prior to examination, written & informed consent will be taken from the patient/guardian. Prior to DW MRI & MRS, proper precautions will be taken & patient will be excluded from study if procedure is contraindicated due to any reason. Appropriate statistical analysis test will be used as per data yield. P value $< 0.05$ was taken as significant.

## RESULTS

The mean age of patients was 42.4±19.1years with 73.4% males and 26.6% were female with male to female ratio was 2.7:1.

In our study 50% patients there were restricted DWI pattern followed by 43.8% free and 6.2% were mild restricted DWI pattern. The mean ADC value in restricted pattern was 0.57±0.1(X10-3mm2/S), in free DWI pattern the mean ADC value was 1.89±0.34 (X10-3mm2/S) and in mild restricted DWI pattern the mean ADC value was 1.2±0.07 (X10-3mm2/S). The mean ADC value in total cases was 1.19±0.68(X10-3mm2/S) (Table: 1).

**Table 1:** DWI pattern with mean ADC value in patients.

| DWI | N | ADC Value (X10-3mm2/S) Mean ± SD |
|---|---|---|
| Restricted | 64 (50%) | 0.57±0.1 |
| Free | 56 (43.8%) | 1.89±0.34 |
| Mild Restricted | 8 (6.2%) | 1.2±0.07 |
| Total | 128 (100%) | 1.19±0.68 |

Table: 2 shows that out of total 128 cases there were 64 cases were had abscess and 64 patients had tumor n final diagnosis according to MRS with DWI. In abscess cases all patients (64) had restricted DWI pattern and in tumor cases 56 patients had free and 8 patients had mild restricted DWI pattern. The mean ADC value in abscess patients was 0.57±0.11(X10-3mm2/S) and in tumor patients mean ADC value was 1.81±0.39 (X10-3mm2/S).

**Table 2:** DWI findings according to Final diagnosis

| DWI Findings | Restricted | Free | Mild Restricted | ADC Value (X10-3mm2/S) Mean ± SD |
|---|---|---|---|---|
| Abscess | 64 (50%) | 0 | 0 | 0.57±0.11 |
| Tumor | 0 | 56 (43.8%) | 8 (6.2%) | 1.81±0.39 |

Table: 3 shows site wise distribution of abscess and tumor patients and found that 82.3% of abscess and 17.7% tumor were present in frontal lobe. Similarly, 0% of abscess and 100% tumor were present Fronto parietal lobe, 100% of abscess and 0% tumor were present in Mid brain, 46.1% of abscess and 53.9% tumor were multifocal in site, 0% of abscess and 100% tumor were present in Occipital Lobe, 76.9% of abscess and 23.1% tumor were present in Parietal lobe, 100% of abscess and 0% tumor were present in Splenium of CC, 0% of abscess and 100% tumor were present in Suprasellar and 0% of abscess and 100% tumor were present in Tempo parietal lobe.

**Table 3:** Site wise distribution of abscess and tumor patients.

| Site | Abscess | | Tumors | | Total | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Frontal Lobe | 28 | 82.3 | 6 | 17.7 | 34 | 26.5 |
| Fronto parietal lobe | 0 | 0 | 2 | 100 | 2 | 1.5 |
| Mid brain | 2 | 100 | 0 | 0 | 2 | 1.5 |
| Multifocal | 12 | 46.1 | 14 | 53.9 | 26 | 20.3 |
| Occipital Lobe | 0 | 0 | 12 | 100 | 12 | 9.3 |
| Parietal lobe | 20 | 76.9 | 6 | 23.1 | 26 | 20.3 |
| Splenium of CC | 2 | 100 | 0 | 0 | 2 | 1.5 |
| Supra sellar | 0 | 0 | 2 | 100 | 2 | 1.5 |
| Tempo parietal lobe | 0 | 0 | 22 | 100 | 22 | 17.2 |
| Total | 64 | 50 | 64 | 50 | 128 | 100 |

Table: 4 shows metabolite detected in abscess and tumors, in abscess majority of metabolite detected were lactate (100%), Acetate and Amino Acids (93.7%), lipids (21.8%), succinates (18.7%), Choline and NAA (9.4%). Similarly, in tumors majority of metabolite detected were lactate (93.7%), lipids (53.1%) Choline and NAA (21.8%) and Acetate, Amino Acids and succinate metabolites were absent in tumors.

**Table 4:** Metabolite detected in abscess and tumors

| Metabolite | Site | Abscess (N=64) | Tumor (N=64) |
|---|---|---|---|
| Lactate | 1.3 | 64 (100%) | 60 (93.7%) |
| Acetate | 1.9 | 60 (93.7%) | 0 (0%) |
| Amino Acids | 0.9-1.3 | 60 (93.7%) | 0 (0%) |
| Choline | 3.2 | 6 (9.4%) | 14 (21.8%) |
| Succinate | 2.4 | 12 (18.7%) | 0 (0%) |
| Lipid | 0.9-1.3 | 14 (21.8%) | 34 (53.1%) |
| NAA | 1.9 | 6 (9.4%) | 14 (21.8%) |

In our study, majority (46.8%) were Glioblastoma followed by Mets (37.5%), Ependymoma (9.3%) and Pilo astrocytoma was present in 6.25% cases (Fig: 1).

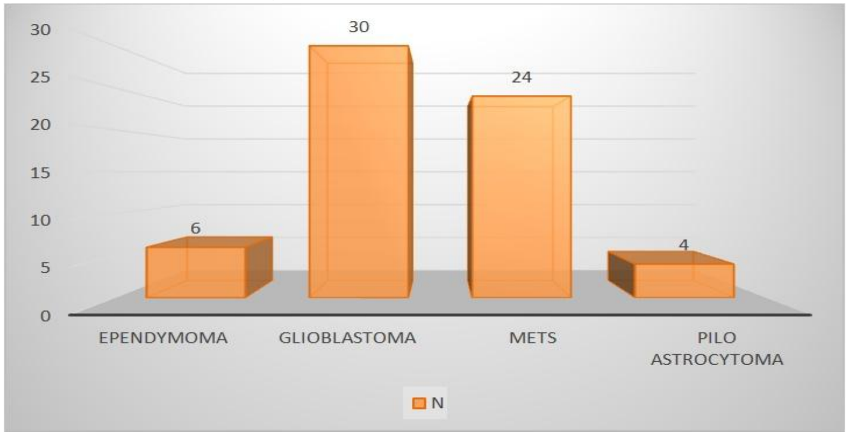


**Figure 1:** Types of tumors present

DWI with MRS was 87.5% sensitive 100% specific in differentiation between brain abscesses and necrotic/cystic brain tumors. The positive and negative predictive values and over all accuracy of MRS and diffusion WI was 100%, 88.9% and 93.7% respectively.

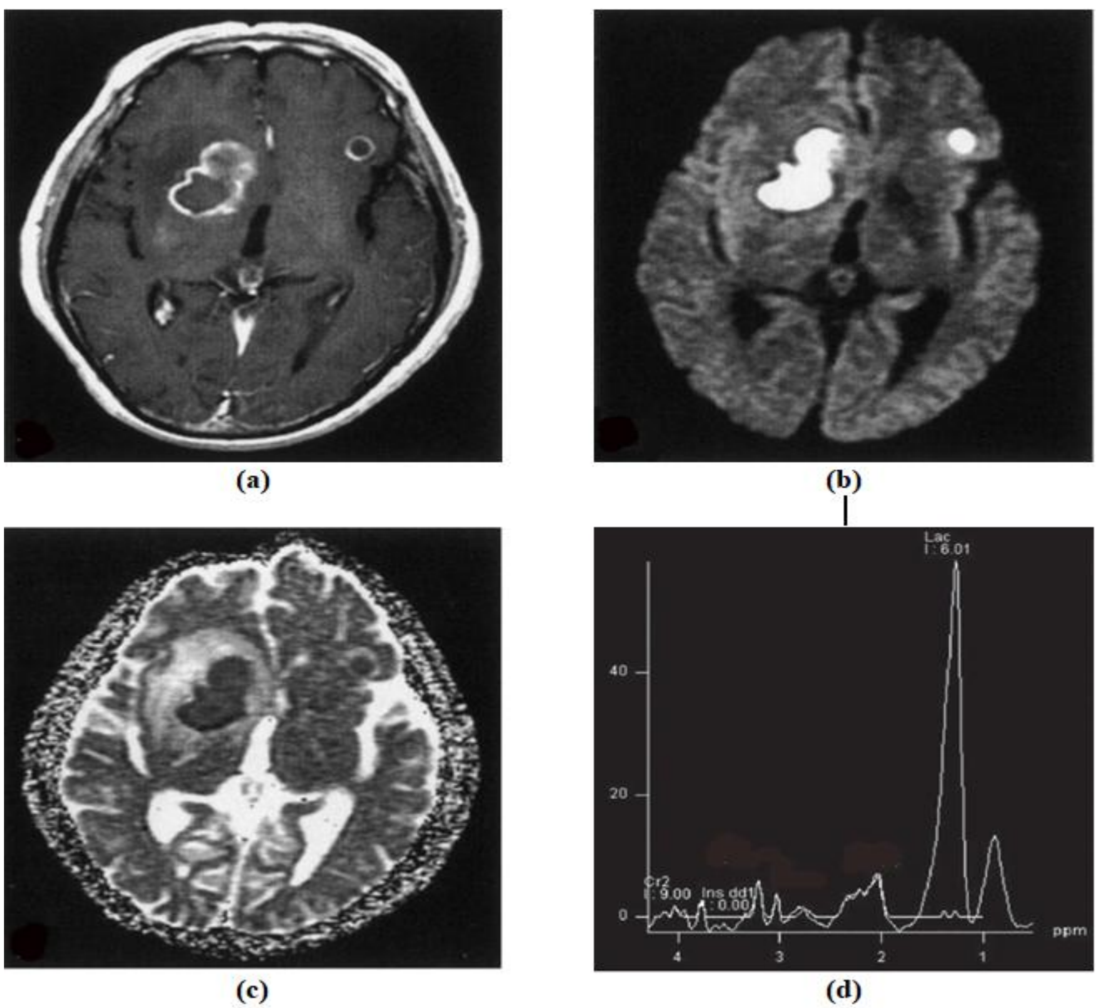


**Figure 2:** Pyogenic Brain abscess with prior antibiotic treatment: Female patient aged 26 years complaining fever with chills. Axial T1 with contrast shows ring shaped enhanced lesion in right basal ganglion and left frontal lobe (a). DWI shows restricted diffusion of the lesion core, mean ADC value $0.6 \times 10^{-3}$ $mm^2/s$ (b & c). MRS shows only lipid and lactate peaks (d).

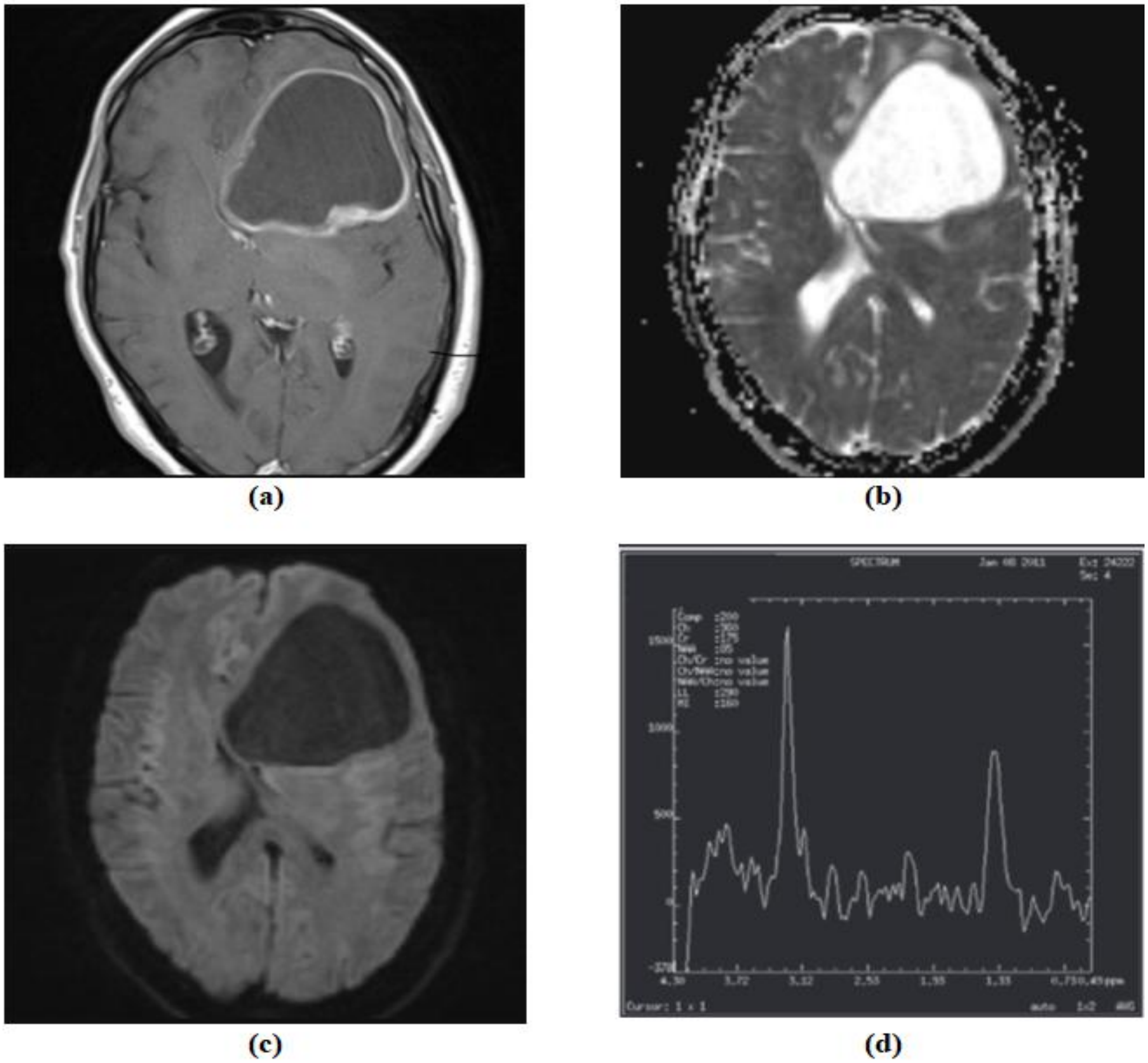

**Figure 3:** Glioblastoma Multiforme: Male patient aged 55 years complaining headache and dizziness. Axial T1 with contrast shows irregular marginally enhanced lesion in left frontal lobe (a). DWI shows free diffusion of the necrotic part of tumor, mean ADC value $1.6 \times 10^{-3}$ $mm^2/s$ (b & c). MRS shows marked increase in Choline and lipid/lactate with marked reduction of NAA and Cr, Ch/Cr 5.4 (d).

## DISCUSSION

In present study, we determined the ability of MRS with diffusion weighted imaging to determine the clinical and radiological difficulties in distinguishing cystic or necrotic tumors from brain abscesses. With current advancement of imaging techniques, it is critical to assess the accuracy and measure the variations of imaging outcomes that support clinical findings.

128 patients were collected from wards and clinics of neurosurgery departments, with MR imaging evidence of ring- shaped enhancement after the injection of contrast material.

The neuroimaging appearance of some cystic or necrotic tumors is comparable to that of brain abscesses and the medical management strategies for abscess and neoplasm are different (13). The spectral characteristics of intracranial abscesses can be summarized as follows: absence of NAA (detected at 2.0 ppm), absence of choline (detected at 3.2 ppm); absence of Cr (detected at 3.0 ppm), presence of cytosolic amino acids such as leucine, isoleucine, and valine (detected at 0.9 ppm); presence of lactate (detected at 1.3ppm), acetate (detected at 1.92 ppm), succinate (detected at 2.4 ppm), and alanine (detected at 1.5 ppm); and occasionally lipids (mostly short- chain fatty acids such as butyric, isobutyric, caproic, propionic, valeric, and isovaleric acids, detected at 0.8–1.2 ppm (13, 14).

In our study the age of patients was 42.4±19.1years. The disease was more prevalent in 3$^{rd}$, 4$^{th}$ and 5$^{th}$

decade of life. There were male preponderance with male to female ratio was 2.7:1. Dina et al found that the abscess group included 11 patients (9 male, 2 female), age range 22–70 years, mean age 46 years, and the tumor group included 19 patients (14 male, 5 female), age range 31–67 years, mean age 39 years (15).

Out of total 128 cases there were 64 cases were had abscess and 64 patients had tumor n final diagnosis according to MRS with DWI. In abscess cases all patients (14) had restricted DWI pattern and in tumor cases 56 patients had free and 8 patients had mild restricted DWI pattern. Majority of abscess was present in frontal lobe followed by parietal lobe and were multi-focal in site. Similarly, tumors were present in frontal lobe followed by parietal and multifocal, tempo parietal lobe. Majority of our tumors were Glioblastoma (46.8%) followed by Mets (37.5%), Ependymoma (9.3%) and Pilocytic astrocytoma was present in 6.25% cases. In study by On diffusion study, Elshafey et al (16) found that central portion of brain abscesses (15 patients) show restricted diffusion in diffusion WI (markedly hyperintense), whereas the necrotic or cystic content of the brain tumors (28 patients) show free diffusion (hypointense) while 2 cases reveal mild restricted diffusion as a result of contamination from previous biopsy. They found that tumors were located in the temp- oro-parietal lobe (n = 13), occipital (n = 9), frontal (n = 4), suprasellar (1), pons (1) and multifocal (n = 2). The abscesses were located in the frontal (4), the parietal (5), Splenium of corpus callosum (n = 1), midbrain (n = 1) and multifocal (n = 4). Elshafey et al (3) found glioblastomas in19 patients, pilocytic astrocytoma in 8 patients and metastases in 3 patients with primary malignancy, bronchogenic carcinoma in two cases and hepatoma in one case.

Here, the mean ADC value in abscess patients was 0.57±0.11(X10-3mm2/S) and in tumor patients mean ADC value was 1.81±0.39 (X10-3mm2/S) with mean ADC value in restricted pattern was 0.57±0.1(X10-3mm2/S), in free DWI pattern the mean ADC value was 1.89±0.34 (X10-3mm2/S) and in mild restricted DWI pattern the mean ADC value was 1.2±0.07 (X10-3mm2/S). Therefore the abscess patients shows high signal intensity on diffusion-weighted images with low ADC value. In concordance with our results, Server et al. (17) reported that Brain abscess displays high signal intensity on diffusion-weighted images with low ADC value. The pus consistency itself could account for the restricted diffusion and therefore high diffusion-weighted imaging signal intensity. Subsequent studies showed the same results (8, 16, 70). All cases of pyogenic brain abscesses showed restricted diffusion and were in good agreement with the findings of these previous studies. Dian et al found that, the necrotic areas of 18 tumors had low signal intensity on DWI with high ADC values (15). Ohba et al. (18) concluded that markedly increased signal intensity of a rim-enhancing brain mass on diffusion-weighted imaging and a low ADC indicating restricted water diffusion are features that should suggest the diagnosis of brain abscess, but are not specific for this diagnosis.

In the study of Chiang et al, (19) as the aim of their study is distinction between pyogenic brain abscess and necrotic brain tumor using 3-tesla MR spectroscopy, diffusion and perfusion imaging resulted that on diffusion-weighted MR images, the central cavities of the cerebral abscesses had very low ADCs, which accounted for the signal hypointensity on ADC map images and the mean ADC values at the central cavities of the cerebral abscesses to be significantly lower than in necrotic tumors, and this coincides with our results of restricted diffusion and lower ADC values in all cases of abscesses cavity versus necrotic/cystic brain tumors (19).

We found that in abscess majority of metabolite detected were lactate (100%), Acetate and Amino Acids (93.7%), lipids (21.8%), succinates (18.7%), Choline and NAA (9.4%). Similarly, in tumors majority of metabolite detected were lactate (93.7%), lipids (53.1%) Choline and NAA (21.8%) and Acetate, Amino Acids and succinate metabolites were absent in tumors. In the study of Lai et al. (13) who studied on fourteen patients (necrotic or cystic tumor [n = 7]; pyogenic abscess [n = 7]) underwent 1.5-T 1H-MRS and diffusion-weighted imaging and had findings of ring-shaped enhancement after contrast agent administration, stated that all cystic tumors and abscesses in their study showed findings of increased lactate, which is a nonspecific metabolite that results from anaerobic glycolysis. And this agrees with our study as all 128 cases (necrotic tumors{n = 64}, pyogenic abscess {n = 64}) show lactate peak. In our study AAs peaks were present only in abscess cases, which is not in agreement with the results of Bartusik et al. (62) that document the visibility of amino acids in the 0.9- ppm region with a 136-ms TE in cases of brain tumors. Dian et al (15) reported that In the tumor group, lactate alone was found in 12 patients, lactate and choline were seen in 5 patients, neither lactate nor choline in 2 patients, lipid and lactate seen in 2 metastatic brain patients, none of the patients showed aminoacids, succinate or acetate. NAA and creatine were reduced or absent in all patients. in the abscess group showed that: the main findings were the resonances of amino acids (valine, leucine, and isoleucine), acetate, alanine, and lactate identified in 9 patients with or without other prominent predominant resonance peaks as N-acetyl aspartate, choline (Cl), and creatine/phosphocreatine and these visible resonances of Cho, Cr, and NAA which may be seen in the abscess may be due to partial volume effects caused by a combination of the resonances from the central cavity and surrounding contrast-enhancing tissue. A resonance peak for succinate was also detected in 1 patient, AAs could not be detected in 2 patients which was probably due to the fact that, these patients under- went treatment with antibiotics for 3 weeks, an extra peak of lipids was found in 3 patients.

Lai et al. (21) reported a decline of the acetate and pyruvate in five patients after 1week of aspiration and medical treatment. They think that the disappearance of metabolites of bacterial origin suggests a positive response to therapy.

Kapsalakia and Fountasa, (22) who study the application of proton MR (1H-MR) spectroscopy in the imaging evaluation of patients harboring intracranial abscess, they concluded that the detection of cytosolic amino acids is a strong indication of an abscess of pyogenic origin and 1H-MR spectroscopy constitutes a valuable diagnostic tool for intracranial abscesses, and this agrees with the present study as amino acids were detected in 60 cases out of 64, and so we agree with previous studies that conclude that 1H-MR spectroscopy constitutes a valuable diagnostic tool for intracranial abscesses, evaluating their evolution and treatment response (22-24).

In our study initially, we found 72 cases of brain abscess and 56 cases of narcotic tumor. Later on, out of 72 cases of brain abscess 8 cases were found to be low grade tumor. Finally, we had 64 cases of abscess and 64 cases of tumor. Thus, DWI with MRS was 87.5% sensitive 100% specific in differentiation between brain abscesses and necrotic/cystic brain tumors. The positive and negative predictive values and over all accuracy of MRS and diffusion WI was 100%, 88.9% and 93.7% respectively. In concordance with our results Elshafey et al (16) found that the combination of 1H-MRS and diffusion-weighted imaging increases the diagnostic accuracy of differentiation between brain abscesses and cystic or necrotic brain tumors. The 15 cases of abscess perfectly match with stereotactic biopsy, while out of 30 cases of tumors 2 are diagnosed by spectroscopy and diffusion WI as low grade tumors and by surgical biopsy and histopathologically as grade IV glioblastoma multiform and two cases as abscess and as necrotic tumor by biopsy and this due to infected tumoral necrotic material biopsy. They found Sensitivity (88%), specificity (100%), PPV (100%), NPV (93.3%) and overall accuracy of MRS and diffusion WI was 95.5%.

## CONCLUSION

Spectroscopic and Diffusion weighted MRI are advanced MR techniques that are used to add important physiological and metabolic information to that obtained with conventional MRI.

H-MRS and diffusion-weighted imaging are fast, easy to perform, non-invasive, and provide additional information that can accurately differentiate between necrotic/cystic tumors and cerebral abscesses. $^{1}$H MR Resonances from succinate (2.4 ppm), acetate (1.9 ppm), and from amino acids (valine, leucine, and isoleucine (0.9 ppm region) are diagnostic abscess markers.

Both DWI and $^{1}$HMRS are useful and efficient imaging techniques in ring enhancing brain lesions and differentiate between brain abscesses and necrotic tumors, but DWI is accurate, had less imaging time than $^{1-}$ HMRS, also DWI is available in many imaging centers.

## BIBLIOGRAPHY

1. Kim YJ, Chang KH, Song IC, Kim HD, Seong SO, Kim YH, Han MH. Brain abscess and necrotic or cystic brain tumor: discrimination with signal intensity on diffusion-weighted MR imaging. AJR Am J Roentgenol. 1998 Dec;171(6):1487-90.
2. Nath K Agarwal M, Ramola M, Husain M, Prasad KN, Rathore RK, et al. Role of diffusion tensor imaging in the differential diagnosis of cystic intracranial mass lesions. Magn Reson Imaging 2009;27(2):198-206.
3. Chun CH, Johnson JD, Hofstetter M, Raff MJ. Brain abscess: a study of 45 consecutive cases. Medicine 1986;65:415-431.
4. Wispelwey B, Decay RG JR, Scheld WM. Brain abscess. In: Scheld WM, Whitley RJ, Durack DT,

eds. Infection of the central nervous system. New York: Raven 1991;457-458.

**5.** Haimes AB, Zimmerman RD, Morgello S, et al. MR imaging of brain abscess. AJR 1989;152:1073-1085.

**6.** Pal D, Bhattacharyya A, Husain M, Prasad KN, Pandey CM, Gupta RK. In vivo proton MR spectroscopy evaluation of pyogenic brain abscess a report of 194 cases. AJNR Am J Neuroradiol 2010; 31(2): 360-6.

**7.** Kapsalaki EZ, Gotsis ED, Fountas KN. The role of proton magnetic resonance spectroscopy in the diagnosis and categorization of cerebral abscess. Neurosurg Focus 2008; 24(6): E7.

**8.** Mishra AM, Gupta RK, Jaggi RS, Reddy JS, Jha DK, Husain N, et al. Role of diffusion weighted imaging and in vivo proton magnetic resonance spectroscopy in the differential diagnosis of ring enhancing intracranial cystic mass lesions. J Comput Assist Tomogr 2004; 28(4): 540-7.

**9.** Kadota O, Kohno K, Ohue S, Kumon Y, Sakaki S, Kikuchi K, Miki H. Discrimination of brain abscess and cystic tumor by in vivo proton magnetic resonance spectroscopy. Neurol Med Chir (Tokyo). 2001 Mar;41(3):121-6.

**10.** Cartez-Zumelzu FW, Stavarow I, Castillo M, et al. Diffusionweighted imaging in the assessment of brain abscesses therapy. Am J Neuroradiol 2004;25:1317.

**11.** Lai PH, Hsu SS, Ding SW, et al. Proton magnetic resonance spectroscopy and diffusion-weighted imaging in intracranial cystic mass lesions. Surg Neurol 2007;68(1):S25–36.

**12.** Hassan MA, Musa KM, Ali II, et al. Role of MR spectroscopy and diffusion weighted techniques in discrimination between capsular stage brain abscesses, necrotic and cystic brain lesions. Med J Cairo Univ 2012;80(1):699–710.

**13.** Lai PH, Ho JT, Chen WI, et al. Brain abscess and necrotic brain tumor: discrimination with proton MR spectroscopy and diffu- sion-weighted imaging. AJNR 2002;23(8):1369–77.

**14.** Akutsu H, Matsumura A, Isobe T, Anno I, Takano S, Itai Y, et al. Chronological change of brain abscess in (1)H magnetic resonance spectroscopy. Neuroradiology 2002;44(7):574–8.

**25.**

**15.** Dina M., Mohamed AA, Ahmed YS. Role of diffusion weighted imaging and proton magnetic resonance spectroscopy in ring enhancing brain lesions. The Egyptian Journal of Radiology and Nuclear Medicine. 2014;45: 825-832.

**16.** Elshafey R, Hassanein O, Shakal A, Mokbel E. 1H proton MR spectroscopy and diffusion-weighted imaging in discrimination between pyogenic brain abscesses and necrotic brain tumors. The Egyptian Journal of Radiology and Nuclear Medicine, 2014 ;45:889–896

**17.** Server A, Kulle B, Maehlen J, Josefsen R, Schellhorn T, Kumar T, et al. Quantitative apparent diffusion coefficients in the characterization of brain tumors and associated peritumoral edema. Acta Radiol 2009;50:682–9.

**18.** Ohba S, Ushioda T, Nakagawa T, Shimizu K, Murakami H. Diffusion magnetic resonance imaging for enhanced visualization of malignant cerebral tumors and abscesses. Neurol India 2011;59(5):674–8.

**19.** Chiang C, Hsieh T, Chiu M, Liu G, Kuo Y, Lin W. Distinction between pyogenic brain abscess and necrotic brain tumour using 3-tesla MR spectroscopy, diffusion and perfusion imaging. Br J Radiol 2009;82:813–20.

**20.** Bartusik D, Aebisher D, Tomanek B. A review of the detection of amino acids in tumor tissue with 1H magnetic resonance spectroscopy in vivo. J Mol Imaging Dyn 2013;2(3):107–12.

**21.** Lai PH, Weng HH, Chen CY, et al. In vivo differentiation of aerobic brain abscesses and necrotic glioblastoma multiforme using proton MR spectroscopy imaging. AJNR 2008;29:1511–8.

**22.** Kapsalakia E, Fountasa KN. Proton MR spectroscopy of brain abscesses. Am J Neuroradiol 2010;31:E67.

**23.** Burtscher IM, Holtas S. In vivo proton MR spectroscopy of untreated and treated brain abscesses. AJNR Am J Neuroradiol 1999;20(6):1049–53.

**24.** Krishna K, Sada E, Vikram A, Gupta A. Multiple brain abscesses – diagnostic dilemma and therapeutic nightmare! J Neurosci Rural Pract 2013;4(2):234–6.