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To Study the Role of Diffusion Weighted Imaging in Differential Diagnosis of Intracranial Cystic Lesions

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Abstract

Background: Enhancing lesions of the brain include abscesses and tumors. The center of abscesses show restricted diffusion and thus high signal intensity on DWI as compared to necrotic tumors which show low signal intensity. Thus DWI is useful in providing a greater degree of confidence in distinguishing brain abscesses from cystic or necrotic brain than conventional MRI. DWI is also an effective way of differentiating an arachnoid cyst from epidermoid tumors. Both lesions present similar signal intensity characteristic of cerebrospinal fluid (CSF) on T1 and T2 sequences. On DWI, epidermoid tumors are hyperintense whereas arachnoid cysts are hypointense, demonstrating high diffusivity. The ADC values of epidermoid tumors are similar to those of the brain parenchyma, whilst ADC values of arachnoid cysts are similar to those of CSF.

Method: This was a prospective study, conducted in a tertiary referral hospital. This consists of a study of 60 patients with intracranial cystic lesions detected on imaging. Data collection for study was started after approval from the institutional research and review board, up to June 2020

Results: DWI was 100% sensitive, 80% specific in diagnosing brain abscesses. The positive and negative predictive values and over all accuracy of DWI was 71.43%, 100% and 86.67% respectively.

Conclusion: DWI can provide valuable information about tumor cellularity and help in the characterization

of tumors and grading of tumors. The solid portion of high grade tumors may show restricted diffusion. True restriction was not observed in low grade gliomas. Incontrast other posterior fossa lesions such as hemangioblastomas and pilocytic astrocytomas do not show true restriction. In the evaluation of extra axial cystic lesions, DWI plays an important role. While conventional MR sequences may be inconclusive in the differentiation of epidermoid cyst from arachnoid cyst, DWI shows restricted diffusion in the former and helps distinguishing the two. DWI shows restricted diffusion in abscesses due to the high viscosity of the coagulative necrosis and thus helps differentiate them from necrotic tumors which do not show restricted diffusion in their center.

Keywords: DWI, MR, Cyst.

Introduction

Diffusion weighted imaging is a technique that assesses local environment at the cellular level to determine changes in the random movement of water protons. Restricted diffusion appears as an area of increased signal on DWI and reduced signal on ADC maps which are calculated from a matrix of tensor vectors obtained in three planes without and with application of diffusion gradients. The amount of diffusion weighting of a DW image depends on the magnitude of the applied gradients, how long they are switched on, and the time between the two lobes.

Water diffusivity in the extracellular space is inversely related to the constituents of intracellular space; cells with a high nucleus to cytoplasm ratio and tissues with high cellularity cause increased volume of intracellular space, resulting in diminished mobility of water protons with restriction of diffusion.

Thus reduced diffusion can be seen in highly cellular tumors such as lymphoma, meningioma and glioblastoma. Several reports have reported an inverse correlation between ADC value and glioma grade for grade II through IV astrocytomas. (1)

The signal intensity of gliomas on DW images is variable (hyper, iso, or hypointense), and a subtle hyperintensity is a common nonspecific finding. However, in the study of Kono et al, the combination of routine image interpretation and ADC values had a higher predictive value. (2) The ADC values of solid gliomas, metastases, and meningioma were in the same range. In cases of lymphomas, however there was a good contrast with white matter, with strongly reduced ADC values. (3) Therefore further studies are needed to define clearly the ability of DWI to help differentiate various brain tumors and to help grade gliomas. (4)

Enhancing lesions of the brain include abscesses and tumors. The center of abscesses how restricted diffusion and thus high signal intensity on DWI as compared to necrotic tumors which show low signal intensity. Thus DWI is useful in providing a greater degree of confidence in distinguishing brain abscesses from cystic or necrotic brain than conventional MRI. (5)

DWI is also an effective way of differentiating an arachnoid cyst from epidermoid tumors. Both lesions present similar signal intensity characteristic of cerebrospinal fluid (CSF) on T1 and T2 sequences. On DWI, epidermoid tumors are hyperintense whereas arachnoid cysts are hypointense, demonstrating high diffusivity. The ADC values of epidermoid tumors are similar to those of the brain parenchyma, whilst ADC values of arachnoid cysts are similar to those of CSF. (6)

Thus DWI has a wide range of applications in the evaluation of intracranial pathological conditions. It provides a specific diagnosis in few situations, and adds to the information provided by conventional sequences in many others. It is in this backdrop, that the objectives set out in this research programme will enable us to understand the appearances of various intracranial cystic lesions on diffusion weighted images. The signal characteristics of these intracranial cystic lesions on ADC images and T2 FLAIR images will also be described.

Materials and Methods

Study Area: Department of Radiodiagnosis, Department of Neurology, Department of neurosurgery, SMS Hospital, Jaipur, Rajasthan.

Source of Data : The source of data for this study were patients referred to the Department of Radiodiagnosis, S.M.S. Medical College Hospital, Jaipur for MRI brain with diffusion weighted imaging. This consists of a study of 60 patients with intracranial cystic lesions detected on imaging.

The MRI was done on the advice of the referring doctor and no patient was made to undergo MRI for the sole purpose of this study.

Study Type: Hospital based cross sectional study and quantitative study

Study Design: Descriptive study

Study Duration: Data collection for study was started after approval from the institutional research and review board, up to June 2020.

Study Tool: Pre-tested, pre-designed proforma was used to collect data.

Sample Size: Sample size was calculated 55 subjects at alpha error 0.05 and power 90% assuming sensitivity of DWI in diagnosing brain abscess and cystic brain tumors 91.6% and 60.7% respectively (assuming histopathological examination as gold standard)as per seed article So, for study purpose 60 cases of intracranial cystic lesions were taken.

Sampling Technique: Every eligible case was included in the study.

Statistical Analysis

- Diagnostic accuracy of DW MRI for differential diagnosis of intracranial cystic lesions was calculated.
- Sensitivity and specificity of DW MRI for differential diagnosis of intracranial cystic lesions was calculated.
- Qualitative data was analysed in terms of percentage and proportion.
- Difference in proportion was analysed with Chi Square test.
- For significance, P value less than 0.05 was considered significant.

Study Population

Patients with complains of headache, fever, epileptic fits, hemiparesis referred to Department of Radiodiagnosis and Modern Imaging for MRI brain at SMS Medical College & Hospital, Jaipur.

Inclusion Criteria

- Patients with intracranial cystic lesion diagnosed on computed tomography or conventional MRI.
- Those who were willing to give written and informed consent were included in study.

Exclusion Criteria

- Patients unfit for MR studies due to orthopedic implants or aneurysmal clips, cardiac pacemaker, implanted cardiac defibrillator, cochlear, otologic or other ear implant, surgical staples, clips or metallic sutures, metallic stent, heart valve prosthesis.
- Patients who were detected to have intracranial bleed and history of trauma were excluded from the study.

Observation And Results

The present study was carried out to describe imaging characteristics of intracranial cystic lesions on DWI and to compare them with ADC and T2 FLAIR images. 60 cases of intracranial cystic lesions were included in the study. The observations of these 60 patients were compiled and analyzed.

Age wise distribution of intracranial cystic lesions

The age of the patients with intra cranial cystic lesions studied ranged from 1 years to 74 years with a mean of 43.97+/-2.04.



Chart 1: Age distribution of intracranial cystic lesions

Intra cranial cystic lesions were found in patients of all age groups. However the peak (23%) was noted in 41-50 years age group (Chart -1).

Sex distribution of intracranial cystic lesions of the 60 patients studied, 20 (32%) were females and 40 (68%) were males.

Chart 2: Sex distribution of intracranial cystic lesions Intra-axial cystic lesions included in study



here were 45 cases of intra axial cystic lesions in this study. The age of the patients ranged from 1 years to 74 years.

Chart 3: Types of intra axial cystic lesions included in the study



Table 1 : Types of non abscess intra-axial lesions included in the study

Non abscess intra-axial lesions	Ν	%
Ependymoma	3	10
Cystic glioma	16	53.3
Cystic metastasis	2	6.66
Pilocytic astrocytoma	4	13.3
Hemangioblastoma	2	6.66
Cystic medulloblastoma	1	3.33
Spindle cell tumor	1	3.33
Hydatid cyst	1	3.33
Total	30	100

Chart: 4 DWI findings in non-abscess intra -axial cystic lesions



Table 2 : DWI findings in intra-axial cystic lesionsaccording to final diagnosis

Type of diffusion		Non abscess
	Abscess	cystic lesion
Restricted	15(33%)	6(13%)
No diffusion	0	24(54%)
restriction		

In abscess cases, all patients (n=15) had restricted DWI pattern and in tumor cases, (n=24) patients had no diffusion restriction, (n=3) patients of high grade glioma had, (n=2)cases of ependymoma, (n=1) case of medulloblastoma with cystic change had patchy restricted diffusion.

Table 3 : Patterns of diffusion restriction

		Fungal	Pyogenic	
		abscess	abscess	
Central dif	fusion	0	10	
restriction		0	10	
Peripheral dif	fusion	5	0	
restriction		5	0	
Table 4: Mean ADC value in different DWI pattern.				
DWI	ADC	Value	$(X10^{-3}mm^2/S)$	
Mean±SD				
Restricted	0.57±0.1			
No diffusion	1.89±	0.34		
restriction				

Extra-axial cystic lesions included in study

There were 15 cases of extra-axial cystic lesions in this study. The age of the patients ranged from 1 years to 74 years.

Chart 5 : Types of extra-axial cystic lesions included in the study







Only 6 cases of extra-axial (epidermoid cysts) cystic lesions showed diffusion restriction.

Table 5: The sensitivity, specificity, positive and negative predictive values and over all accuracy of diffusion weighted imaging in diagnosing brain abscess assuming histopathological findings as gold standard.

True positive	15
False positive	6
False negative	0
True negative	24

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Sensitivity	100%
Specificity	80.00%
Positive Predictive Value	71.43%
Negative Predictive Value	100%
Accuracy	86.67%

Here, DWI was 100% sensitive, 80% specific in diagnosing brain abscesses. The positive and negative predictive values and over all accuracy of DWI was **71.43%**, **100% and 86.67% respectively.**

Case Illustrations

Some of the representative cases have been reported in detail, in the following section, along with their respective images.

Case 1

24 years old male patient presented with history of fever, altered sensorium ,nausea vomiting for 16days, MRI BRAIN was done.

Findings: Well defined round lesion with a T2 hypointense and T1 isointense rim noted in right temporal lobe. The centre of the lesion is hyperintense on DWI and hypointense on ADC, ADC value of restricted part was(~ 0.45×10^{-3} mm²/s) and T2 FLAIR images. There is moderate adjacent edema and mass effect.

Diagnosis: Pyogenic cerebral abscess.



T1W



T2W





Sagittal T2W

DWI

Case 2

T1 Post Contrast

ADC

Age: 10 years old

Sex: Female

Clinical Data: Four weeks history of ataxia and right sided hemiparesis followed by nausea and vomiting on and off associated with headache. Fundoscopic examination revealed papilledema

Findings: MRI brain with contrast was done for evaluation of ataxia and right sided hemiparesis. T1,T2, FLAIR, DWI, MRS, T1 post contrast images were taken in axial, sagittal, and coronal planes., axial T1, axial T2, axial FLAIR, show multilocular cystic lesion measuring (86x61x59mm), which is slightly hyperintense to CSF on T1W image and hyperintense on T2W image noted in left parieto-occiptal region with minimal perilesional oedema causing midline shift, effacement of sulci . axial DWI does not show any diffusion restriction and ADC IMAGE . shows no obvious contrast enhancement in the lesion.(ADC VALUE~ 3.39 X 10⁻³mm²/s)

Diagnosis: Hydatid cyst





T1W





DWI

ADC

Case 3

Age: 22 years old

Sex: Male

Clinical Data: Known case of B Cell ALL on treatment, now presented with fever, altered Sensorium for 16 days

Findings: Axial T2W image shows a heterointense lesion in right temporal lobe with an irregular hypointense wall with internal haemorrhage. Post contrast axial T1W image shows peripheral enhancement of the wall with no enhancement of intracavitary projections. DWI shows hyperintensity in the projections with hypointensity in the cavity. Culture from pus grew ASPERGILLUS FLAVUS. (ADC value of restricted part was ~2.21 x 10⁻³mm²/s)

Final Diagnosis: Fungal brain abscess with haemorrhagic component (Aspergillus flavus)









ADC

Post contrast

Case 4 Age: 55yrs

Sex: Male

Clinical Data: 2 weeks history of headache not alleviated by analgesics

Findings: intraaxial Large mass at right temporoparietal region. It is largely cystic/necrotic, has ring enhancement and solid heterogeneous enhancement anterosuperiorly. It extends to the subependymal of trigone and posterior temporal horn. Bright FLAIR signal extends into right anterior temporal pole and internal capsule posterior limb as well as the overlying cortex. There is free diffusion (ADC VALUE~2.84 X 10^{-3} mm²/s). There is trans tentorial herniation with midbrain distortion and midline shift to left.

Final Diagnosis: Cystic glioma

FLAIR

T1W





Post Contrast





DWI

Case 5

ADC

Age: 29 years old

Sex: Female

Clinical Data: 29 years old female patient known case of ALL presented with fever, altered sensorium and seizures of 7 days duration

Findings: Multiple T2/FLAIR hyperintense lesions in B/L frontal lobes with surrounding vasogenic odema, lesions showed peripheral irregular enhancement with diffusion restriction in enhancing part, (ADC values of restricted part ~2.03 x 10^{-3} mm²/s) findings were consistent with multiple fungal abscesses on follow up size of the lesions were reduced after antifungal therapy

Final Diagnosis: Fungal abscess



DWI



ADC

Post contrast

Discussion

Diffusion weighted MRI provides image contrast that is different from that provided by conventional MRI sequences. It provides a technique for mapping proton contrast that reflects the microvascular environment. This imaging technique is sensitive to early ischemic insult. DWI is performed with a pulse sequence capable of measuring water translation over short distances. This water diffusion is much slower in certain pathological conditions as compared with normal brain. (7)

In this study, 60 patients with intracranial cystic lesions detected on DW MRI of the brain were included. It was found that DW MRI plays an important role in diagnosis of pyogenic and fungal brain abscesses, high grade cystic gliomas, and also differentiates them.

DWI MRI can also be used to differentiate between extra axial benign lesions such as

arachnoid cyst, epidermoid cyst, neuroenteric cyst. Reviewed the diffusion-weighted images and ADC maps of intracranial tumors with a cystic presentations (such as Hemangioblastoma, pilocytic astrocytoma, craniopharyngioma, rathke cleft cyst) on CT and conventional MR studies, most of them also showed increased diffusion of necrotic/cystic components.

In the present study, we have noticed that most pyogenic brain abscesses showed central hyperintensity on diffusion weighted imaging with low ADC SI and value, the ADC values ranging $0.9-0.13 \times 10^{-3} \text{ mm}^2/\text{s}$.

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These results were in agreement with the results of Ebisu et al., Kim et al., Desprechins et al., Lai et al., Reddy et al. and Alam et al. (1,5). Whereas, All fungal brain abscesses showed peripheral hyperintensity on DW images with corresponding fall on ADC. 2 cases of fungal brain abscess in our study showed haemorrhagic component, pus culture revealed aspergillus flavus in both cases.

DW imaging was superior to conventional MR imaging in evaluating the success or failure of abscess therapy. Decreased signal intensity on trace DW images and increasing ADC values in the abscess cavity were correlated with successful treatment. Conversely, persisting or reappearing high signal intensity in the abscess cavity on trace DW images and low ADC values indicating restricted diffusion were seen in cases of treatment failure and were correlated with pus reaccumulation(8).

In the current study, we included 16 cases of cystic glioma (both high and low grade) and 2 cases of cystic brain metastases.

In present study, cystic or necrotic brain tumors (except 3 cases of high grade glioma with high SI in DWI and low SI in ADC map) had hypointense signals on diffusion weighted imaging and high signals in ADC and value ranging up to $2.2\pm 0.9 \times 10^{-3}$ mm2/s denoting free diffusion, these results are in agreement with study done by Noguchi et al. and Besada et al. (9,10,11).

DWI MRI in Abscess and Necrotic Malignant Tumors

Several studies have showed that DWI can differentiate necrotic tumors from abscesses as both can show rim like enhancement on post contrast images.

Lai et al (47) have showed that abscess cavity shows high signal intensity on DWI and a low signal on ADC image. This is not seen in the necrotic component of brain tumors.

They concluded that DWI may enable one to distinguish brain tumors from necrotic tumors. Also it helps in the evaluation of partially treated abscesses and to look for their recurrence.

In this study, 100% of cases of abscess showed true diffusion restriction. The cystic or necrotic component of 3 cases of high grade glioma included in this study showed patchy diffusion restriction.

All 10 cases of pyogenic brain abscesses showed central diffusion restriction and 5 cases showed peripheral diffusion restriction with intracavitatory projections, these cases came out as fungal abscesses on histopathology. In the study, Ashdown et al (11) described 4 cases of fungal abscesses in patients who were immunocompromised; these abscesses had an irregular T2 hypointense rim that showed postcontrast enhancement.

We found restriction on DWI with low ADC values $(0.62 \pm 0.17 \times 10^{-3} \text{mm}^2/\text{s})$ in the cavity of the pyogenic abscesses similar to findings reported previously(12). Low ADC values between 0.28 and $0.70 \times 10^{-3} \text{ mm}^2/\text{s}$ have been reported in bacterial abscesses and ascribed to the presence of intact inflammatory cells and bacteria that collectively impede the microscopic motion of water molecules(13) Extra axial lesions

Diffusion weighted MR plays a key role in differentiating arachnoid from epidermoid cysts. Schaefer et al (14) showed that conventional MR cannot be reliably used to differentiate these two lesions as both have CSF like signal intensity on conventional MR sequences. However on DWI epidermoid cyst shows restricted diffusion while arachnoid cyst shows CSF like intensity. This was also demonstrated in a study by Cruz et al (15), in which epidermoid cysts had ADC values similar to brain parenchyma while arachnoid cysts had ADC values similar to CSF. In this study all 6 cases of arachnoid cysts had signal similar to CSF on DWI and ADC images. All 4 cases of epidermoid cysts noted in this study had restricted diffusion.

Summary And Conclusion

Diffusion weighted MRI is a valuable technique that provides unique information about the physiological state of brain tissue. The current study comprised 60 patients evaluated in .S.M.S. Medical College Hospital, Jaipur, who underwent DW MRI of the brain when they were referred for suspected intracranial cystic lesions. All the MRI scans in this study were performed using 3 T MRI scanner (INGENIA). Many intracranial cystic lesions were found. By using a combination of various MR sequences coupled with DWI and ADC images a valuable diagnosis may be provided to the clinicians. In this study the signal characteristics of various lesions on DWI, ADC, T2FLAIR and T1W images were studied.

DWI can provide valuable information about tumor cellularity and help in the characterization of tumors and grading of tumors. The solid portion of high grade tumors may show restricted diffusion. True restriction was not observed in low grade gliomas. Incontrast other posterior fossa lesions such as hemangioblastomas and pilocytic astrocytomas do not show true restriction.

In the evaluation of extra axial cystic lesions, DWI plays an important role. While conventional MR sequences may be inconclusive in the differentiation of epidermoid cyst from arachnoid cyst, DWI shows restricted diffusion in the former and helps distinguishing the two. DWI shows restricted diffusion in abscesses due to the high viscosity of the coagulative necrosis and thus helps differentiate them from necrotic tumors which do not show restricted diffusion in their center.

Diffusion-weighted imaging is non-invasive and relatively low cost, it has been widely applied to the diagnosis of various diseases including the detection of abscesses from cystic necrotic tumors. and distinguishing epidermoid from arachnoid cysts. Diffusion imaging can aid in the diagnosis, further management plan and also follow up of brain abscess after antibiotic therapy or surgical interference. DWI can also help in distinguishing cerebral pyogenic abscess and fungal abscesses as they show different pattern of diffusion restriction as in our study. So it helps in improved patient care. This sequence should be used as an addition to conventional imaging and not as replacement for histopathology.

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