ORIGINAL RESEARCH

To Evaluate the Features of Intracranial Lesions on Diffusion Weighted Magnetic Resonance Imaging

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ABSTRACT
Aim: To evaluate the features of intracranial lesions on diffusion weighted magnetic resonance imaging. **Materials and methods:** The present hospital-based prospective observational study was conducted in the Department of Radiology, Muzaffarnagar Medical College, Muzaffarnagar, U.P. for 18 months duration among 50 patients who were detected to have intracranial lesions on MRI brain. Relevant clinical history and examination were noted. The DWI findings were noted and correlated with ADC and T2 FLAIR images. For evaluation of the brain, MRI was performed using a 1.5 tesla MRI scanner (MAGNETOM ESSENZA SIEMENS). Sagittal T1, axial T2 FLAIR and diffusion-weighted images with ADC maps were taken. **Results:** Most common diagnosis among the study subjects was acute infarct (32%). 34 cases (68%) showed hyperintensity on DWI of which true restriction (hyperintense on DWI and hypointense on ADC) was noted in 31 patients (62%). There were 6 cases of intra axial tumors in this study, out of which 4 cases (66.7%) showed true diffusion restriction. Of these were 1 were GBM, 1 medulloblastomas, and one was lymphoma and 1 case of cerebral metastasis. In 2 cases of oligodendroglioma ADC signal was increased in all, suggesting increased water diffusivity. 10 cases of extra axial tumors were included in this study. **Conclusion:** Diffusion-weighted MRI is a valuable technique that provides unique information about the physiological state of brain tissue. By using a combination of various MR sequences coupled with DWI and ADC images a valuable diagnosis may be provided to the clinicians.

Keywords: Intracranial Lesions,DWI, ADC

INTRODUCTION

Diffusion-weighted imaging is a technique that assesses the local environment at the cellular level to determine changes in the random movement of water protons. 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. Acute cerebral infarct results in anoxic injury to the cell membrane, which results in the reduced movement of water molecules between intra and extra-cellular compartments. Therefore, the earliest imaging feature of stroke is hyperintensity on DWI. ADC values vary with the age of the ischemic stroke, a factor that can directly affect the analysis of clinical cases. In the first few hours after the onset of ischemia, water diffusion decreases rapidly. After about 24 hours, it rises and reaches normal values by 5 to 7 days. After about two weeks, diffusion typically increases within the territory of the infarct.[1]

DWI is often used to identify acute arterial ischemia. Other processes that interfere with or restrict water movement can cause notable changes in DWI, including pyogenic abscesses, neoplastic lesions, encephalitis and occasionally demyelinating diseases.[2] Reduced diffusion can be seen in highly cellular tumors such as glioblastoma, meningioma and lymphoma. Several reports have observed an inverse correlation between ADC value and glioma grade for grade II through IV astrocytomas.[2,3]

The signal intensity of gliomas on DW images is variable (hypointense, isointense or hyperintense) and a subtle hyperintensity is a common non-specific finding. Tumor cellularity is a major determinant of ADC values of brain tumors, although there are others. ADC values cannot be used in individual cases to differentiate glioma types reliably (the ADCs of patients with grade II astrocytoma and glioblastoma overlap). However, in the study of Kono et al., the combination of routine image interpretation and ADC values had a higher predictive value.[3] A study by Tadeusz et al., however, showed no significant advantage of DWI in the grading of gliomas. 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. Therefore, further studies are needed to define the ability of DWI to help differentiate various brain tumors and help grade gliomas.[4,5]

Enhancing lesions of the brain include abscesses and tumors. The center of abscesses shows restricted diffusion and thus high signal intensity on DWI compared to necrotic tumors, which show low signal intensity. Therefore, DWI helps provide a greater degree of confidence in distinguishing brain abscesses from cystic or necrotic brain tumors than conventional MRI.[6]

Against this backdrop, the objectives set out in this research enabled us to understand the appearances of various intracranial lesions on diffusion-weighted images. The signal characteristics of these lesions on ADC images and T2 FLAIR images are also described. The objectives of the study are to describe the features of intracranial lesions on Diffusion-Weighted Imaging and to compare the Diffusion Weighted Imaging features of these lesions with ADC and T2 FLAIR images to help differentiate among them.

MATERIALS AND METHODS

The present hospital-based prospective observational studywas conducted in the Department of Radiology, Muzaffarnagar Medical College, Muzaffarnagar, U.P. for 18 months duration (12 months for data collection and six months for data analysis).Patients of all age groups and both sexes who were clinically suspected of intracranial lesions were referred from the Department of Medicine, Paediatrics and Surgery, Muzaffarnagar Medical College, Muzaffarnagar, for MRI brain, in the Department of Radio-diagnosis.

SAMPLE SIZE

Sample size = 50 cases (Hospital-based study depending on the duration period for data collection according to the last three years average).

SAMPLING TECHNIQUE

Simple Random Sampling

INCLUSION CRITERIA

All patients who were detected to have any of the following intracranial lesions on MRI brain:

1. Infarction
2. Demyelinating disorders
3. Degenerative disorders
4. Infective conditions
5. Tumors
6. Metabolic or toxic insults to the brain

EXCLUSION CRITERIA

- Patients who were detected to have an intracranial bleed.
- Patients with pacemakers, metallic implants and aneurysmal clips.
- Patients with claustrophobia.

PROCEDURE

In all patients detected to have intracranial lesions on MRI of the brain, at the Department of Radiodiagnosis, Muzaffarnagar Medical College, Muzaffarnagar, written and informed consent were taken from the patient or guardian (in case of a minor). Relevant clinical history and examination were noted. The DWI findings were noted and correlated with ADC and T2 FLAIR images.

Based on their signal intensity, these lesions were grouped into one of the following:

1. DWI hyperintense, ADC hypointense, T2 FLAIR isointense
2. DWI hyperintense, ADC iso-hyperintense, T2 FLAIR hyperintense
3. DWI hyperintense, ADC hypointense, T2 FLAIR hyperintense
4. DWI isointense, ADC hyperintense, T2 FLAIR hyperintense
5. DWI hypointense, ADC hyperintense, T2 FLAIR hyperintense
6. DWI hypointense, ADC hyperintense, T2 FLAIR isointense

For evaluation of the brain, MRI was performed using a 1.5 tesla MRI scanner (MAGNETOM ESSENZA SIEMENS). Sagittal T1, axial T2 FLAIR and diffusion-weighted images with ADC maps were taken.

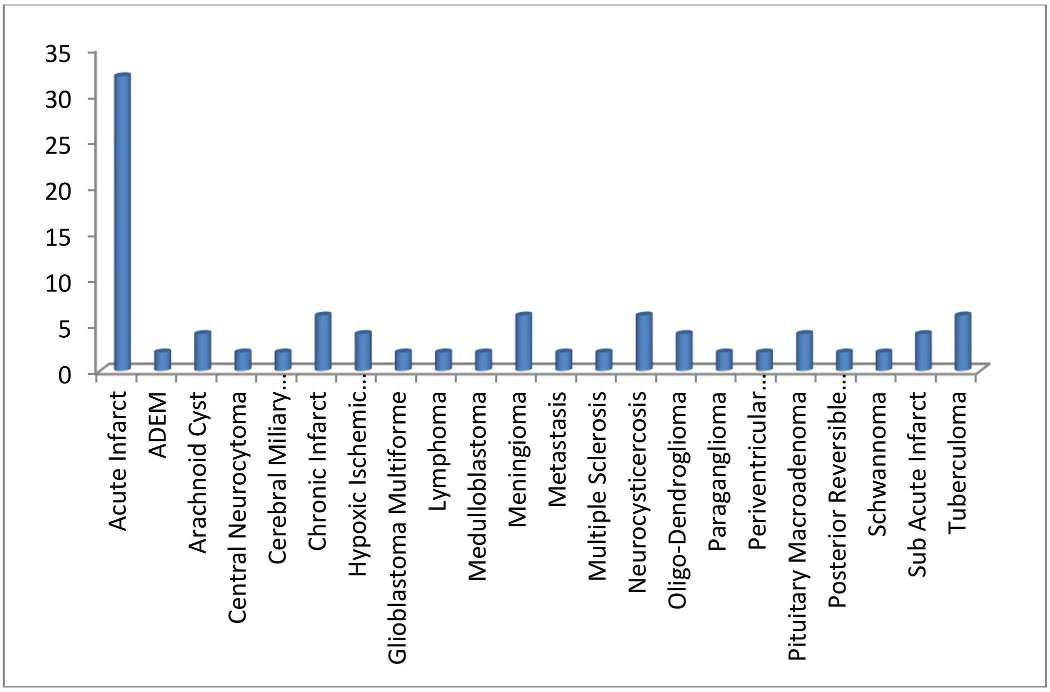
STATISTICAL ANALYSIS

Data was collected and subjected to statistical analysis using SPSS version 24.

RESULTS

In this study, male and female comprised of 64% and 36% of the subjects respectively. Maximum subjects were from age group of 41-60 years (34%) followed by 21-30 years (26%). Only 4% of the subjects were of age group upto10 years. Most common diagnosis among the study subjects was acute infarct (32%). Chronic Infarct, meningioma, neurocysticercosis and tuberculoma was reported in 6% of the subjects each. Lymphoma and medulloblastoma was found in 1 subject each (graph 1).

In both male and female, acute infarct was the most common diagnosis reported. Tuberculoma and lymphoma was revealed only in males but meningioma was shown more in females (table 1). In all the age group except upto 10 years, acute infarct was the most common lesion while in subjects upto 5 years, hypoxic ischemic encephalopathy was the most common lesion (table 2).



Graph 1: Diagnosis among the study subjects

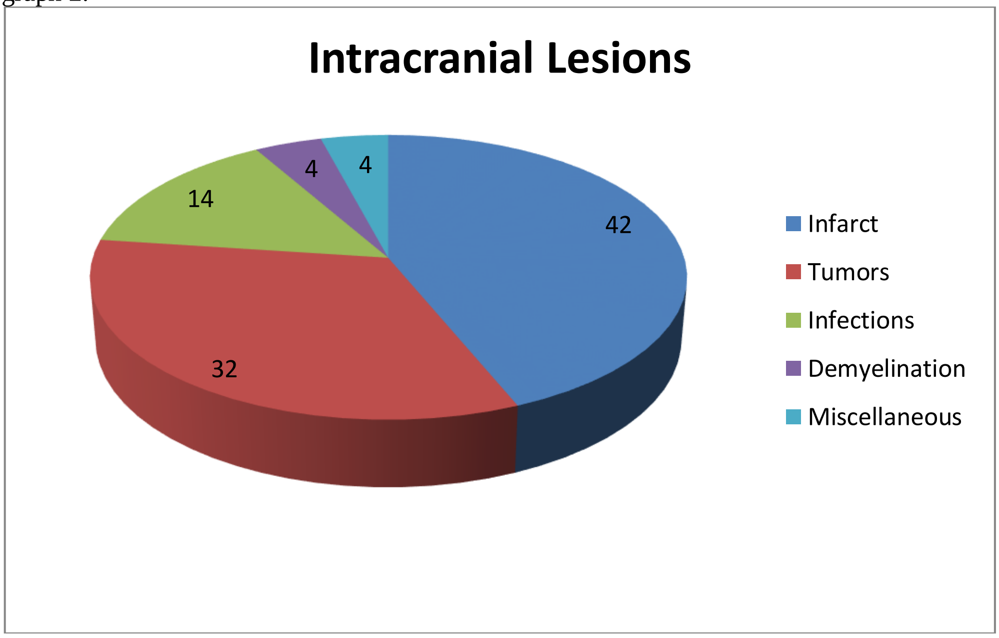
Table 1: Diagnosis according to gender among the study subjects

Diagnosis	Sex		Total
	Female	Male	
Acute Infarct	7	9	16
ADEM	1	0	1
Arachnoid Cyst	1	1	2
Central Neurocytoma	0	1	1
Cerebral Miliary Tuberculosis	1	0	1
Chronic Infarct	0	3	3
Glioblastoma Multiforme	1	0	1
Infective Etiology Tuberculoma	1	0	1
Lymphoma	0	1	1
Medulloblastoma	1	0	1
Meningioma	2	1	3
Metastasis	0	1	1
Multiple Sclerosis	0	1	1
NCC	1	0	1
Neurocysticercosis	0	1	1
Oligodendroglioma	0	2	1
Paraganglioma	0	1	1
Periventricular Leukomalacia	0	1	1
Pituitary Macroadenoma	0	2	2
Posterior Reversible Encephalopathy Syndrome (PRES)	1	0	1
Schwannoma	0	1	1
Sub-AcuteInfarct	0	2	2
Tuberculoma	0	3	3
Hypoxic Ischemic Encephalopathy	1	1	2
Total	18	32	50

Table 2: Diagnosis according to age among the study subjects

Diagnosis	Age Group (in years)					
	<5	5-10	11-20	21-40	41-60	>60
Acute Infarct	0	0	2	4	7	3
ADEM	0	0	0	1	0	0
Arachnoid Cyst	0	0	0	1	0	1
Central Neurocytoma	0	0	1	0	0	0
Cerebral Miliary Tuberculosis	0	0	0	1	0	0
Chronic Infarct	0	0	0	0	1	2
Glioblastoma Multiforme	0	0	0	1	0	0
Infective Etiology Tuberculoma	0	0	1	0	0	0
Lymphoma	0	0	1	0	0	0
Hypoxic Ischemic Encephalopathy	2	0	0	0	0	0
Medulloblastoma	0	0	0	1	0	0
Meningioma	0	0	0	2	0	1
Metastasis	0	0	0	0	1	0
Multiple Sclerosis	0	0	0	1	0	0
NCC	0	1	0	0	0	0
Neurocysticercosis	0	0	0	0	0	1
Oligodendroglioma	0	0	0	0	2	0
Paraganglioma	0	0	1	0	0	0
Periventricular Leukomalacia	0	1	0	0	0	0
Pituitary Macroadenoma	0	0	0	1	1	0
Posterior Reversible Encephalopathy Syndrome (PRES)	0	0	1	0	0	0
Schwannoma	0	0	0	0	1	0
Sub-Acute Infarct	0	0	0	0	2	0
Tuberculoma	0	0	1	0	2	0
Total	2	2	8	13	17	8

Of the total cases included in this study, infarcts were the majority which constituted 21 cases (42%). The other cases were 16 cases of tumors (32%) of which 6 (12%) were intra axial and 10 (20%) were extra axial tumors, 7 infective conditions (14%), 2 casesof demyelination (4%) and 2 other miscellaneous conditions (4%). These included 1 case of periventricular leukomalacia, and 1 posterior reversible encephalopathy syndrome cases as shown in graph 2.



Graph 2: Types of intracranial lesions

Of the 50 patients included in this study, 34 cases (68%) showed hyperintensity on DWI of which true restriction (hyperintense on DWI and hypointense on ADC) was noted in 31 patients (62%). This constituted 62% of the cases showing diffusion restriction. T2 shine through was noted in 3 patients (6%). 8 patients (16%) showed T2 washout (hyperintense on T2WI and isointense on DWI. 16 patients (32%) had lesions that showed increased diffusivity (hyperintense signal on ADC image). Of these 7 (14%) were hypointense on DWI. This constituted 32 % of the cases showing increased diffusivity. In 14 cases (66.67%) the infarcts were in MCA territory, in 2 cases (9.52%) they were in ACA territory, in 3 cases (14.29%) the infarcts were in PCA territory and in 2 cases (9.52%) they were in basilar artery and vertebral artery territory (table 3).

Table 3: Infarct and territory

Territory	N	%
MCA	14	66.7
ACA	2	9.52
PCA	3	14.29
Basilar artery and vertebral artery territory	2	9.52

There were 6 cases of intra axial tumors in this study. This included 1 (16.67%) lymphoma, 1 (16.67%) glioblastoma multiforme 2 (16.67%) cases of oligodendroglioma, 1 (16.67%) medulloblastoma 1 (16.67%) case of cerebral metastasis. 4 cases (66.7%) showed true diffusion restriction. Of these were 1 were GBM, 1 medulloblastomas, and one was lymphoma and 1 case of cerebral metastasis. In 2 cases of oligodendroglioma ADC signal was increased in all, suggesting increased water diffusivity. 10 cases of extra axial tumors were included in this study. These were 2 cases of arachnoid cysts, 3 cases of meningiomas, 1 case of schwannomas, 2 cases of pituitary macroadenoma, 1 case of paraganglioma, 1 case of central neurocytoma. True restricted diffusion was noted in 6 cases (60%). This included 2 (33.3%) cases of pituitary macroadenoma, 1 (16.7%) case of central neurocytoma and 3 cases (50%) of meningiomas. 1 case of schwannoma showed T2 washout (table 4).

Table 4: Intra axial and extra axial tumors

Intra axial tumors	Restriction	No Restriction
Lymphoma	1	0
Glioblastoma Multiforme	1	0
Oligodendroglioma	0	2
Medulloblastoma	1	0
Cerebral Metastasis	1	0
Extra axial tumors		
Arachnoid Cysts	0	2
Meningiomas	3	0
Schwannomas	0	1
Pituitary Macroadenoma	2	0
Paraganglioma	0	1
Central Neurocytoma	1	0

DISCUSSION

Diffusion-weighted (DW) magnetic resonance (MR) imaging provides potentially unique information on the viability of brain tissue. It provides image contrast dependent on the molecular motion of water, which may be substantially altered by disease. It is particularly sensitive for the detection of acute ischemic stroke and differentiation of acute stroke from other processes that manifest with sudden neurologic deficits. Diffusion-weighted MR imaging also provides adjunctive information for other cerebral diseases, including neoplasms, intracranial infections, traumatic brain injury, and demyelinating processes. 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].

The present hospital-based prospective observational study was conducted in the Department of Radiology, Muzaffarnagar Medical College, Muzaffarnagar, U.P. among 50 patients of all age groups and both sexes who are clinically suspected for intracranial lesions The aim of the study was to describe the features of intracranial lesions on Diffusion-Weighted Imaging and compare the Diffusion-Weighted Imaging features of these lesions with ADC and T2 FLAIR images so as to help differentiate among them.

In this study, males and females comprised 64% and 36% of the subjects, respectively. Hence there was male dominancy in the present study. Similar male dominancy was P. Pradeep Kumar Reddy et al.[8], Shrishail Patil et al.[9], V. Vishwas Chakra et al.[10]and Shubham Gupta et al.[11] in their studies.

Maximum subjects were from the age group of 41-60 years (34%), followed by 21-30 years (26%). Only

4% of the subjects were of age group up to 10 years. Similar age distribution was reported by V. Vishwas Chakra et al.[10].In a study by Shrishail Patil et al.[9], the mean age among females was 50 years and the mean age among males was 44 years. These findings are approximately similar to our study. According to Amira I. Baghdady et al.[12], ages ranged from 2 to 72 years, with a mean of 35.5 years.

Of the total cases included in this study, infarcts were the majority which constituted 21 cases (42%). The other cases were 16 cases of tumors (32%), of which 6 (12%) were intra-axial and 10 (20%) were extra-axial tumors, 7 infective conditions (14%), 2 cases of demyelination (4%) and 2 other miscellaneous conditions (4%). These included 1 case of periventricular leukomalacia and one posterior reversible encephalopathy syndrome case. In both males and females, acute Infarct was the most common diagnoses reported. Tuberculoma and lymphoma were revealed only in males, but meningioma was shown more in females. In all the age groups except up to 10 years, acute Infarct was the most common lesion, while in subjects up to 5 years, hypoxic-ischemic encephalopathy was the most common lesion. Similarly, in a study done by Shrishail Patil et al.[9], infarcts were the majority which, constituted 52 cases (45.2%). 4 cases of hypoxic-ischemic encephalopathy (3.4%) were also included. The other cases were 36 cases of tumors (31.3%) of which 19(52.8%) were intra axial and 17(47.2%) were extra-axial tumors, 15 infective conditions (13%), 4 cases of demyelination (3.4%) and 4 other miscellaneous conditions (3.4%).In a study by V. Vishwas Chakra et al.[10], the majority were infarcts which constituted 52 cases (45.2%), 4 cases of hypoxic-ischemic encephalopathy (3.4%) were also included. The other cases were tumors (31.3%), of which 19 (52.8%) were intra axial and 17 (47.2%) were extra-axial tumors, 15 infective conditions (13%), 4 cases of demyelination (3.4%) and 4 other miscellaneous conditions (3.4%).

Of the 50 patients included in this study, 34 cases (68%) showed hyperintensity on DWI, of which true restriction (hyperintense on DWI and hypointense on ADC) was noted in 31 patients (62%). This constituted 62% of the cases showing diffusion restriction. T2 shine through was noted in 3 patients (6%). 8 patients (16%) showed T2 washout (hyperintense on T2WI and isointense on DWI. 16 patients (32%) had lesions that showed increased diffusivity (hyperintense signal on ADC image). Of these 7 (14%) were hypointense on DWI. This constituted 32 % of the cases showing increased diffusivity.

In a study by Shrishail Patil et al.[9], 82 cases (71.2%) showed hyperintensity on DWI, of which true restriction (Hyperintense on DWI and hypointense on ADC) was noted in 52 patients (45.2%). This constituted 63.4% of the cases showing diffusion restriction. T2 shine-through was noted in 30 patients (26%). This constituted 36.6% of the cases showing diffusion restriction. 52 cases (45.2%) showed hypointensity on ADC images. All of these were hyperintense on DW images. 13 patients (11.3%) showed T2 washout (Hyperintense on T2WI and isointense on DWI). 5 patients (0.43%) showed no signal change on DWI or ADC images. 51 patients (44.3%) had lesions that showed increased diffusivity (hyperintense signal on ADC image). Of these 15 (13%) were hypointense on DWI. According to Shubham Gupta et al[11], 33 cases (46%) showed hyperintensity on DWI, of which true restriction (hyperintense on DWI and hypointense on ADC). T2 shine-through was noted in 16 patients (22%). 9 patients (12%) showed T2 washout (isointense on DWI). 13 patients (18%) showed no signal change on DWI or ADC images.

Infarcts constituted 21 cases (42%) of the total cases in this study. Of this, 16 (76.19%) were acute infarcts, 3 (14.29%) were chronic infarcts and 2 (9.52%) were subacute infarcts. In 14 cases (66.67%), the infarcts were in MCA territory. In 2 cases (9.52%), they were in ACA territory, in 3 cases (14.29%), the infarcts were in PCA territory and in 2 cases (9.52%), they were in basilar artery and vertebral artery territory. All 16 cases (76.22%) of acute infarcts showed true diffusion restriction with hyperintensity on DWI and hypointensity on ADC images. Of these, 16 cases showed hyperintensity on T2W images. Of the 3 cases of chronic infarcts, the ADC signal was increased in all, suggesting increased water diffusivity. Out of 2 cases of subacute infarcts, 1 (50%) showed true restriction and 1 (50%) showed T2 shine through. Thus, DWI not only helped detect all cases of acute infarcts but also proved to be a valuable tool in categorizing the infarcts as acute, chronic and subacute infarcts.

This is comparable to a study done by Van Der Zwan et al[13], which showed that MCA territory is the most common site for infarcts and ACA territory is the least common among major arterial territories. In chronic infarcts, the signal on DWI and ADC images is variable and depends on a combination of T2 signal and increased ADC values. The T2 signal is also affected by the onset of cystic encephalomalacia. The results of this study are correlated with a study done by Gonzalez et al[14], who concluded that DWI is superior to conventional MRI in the diagnosis and characterization of acute infarct.Similarly, Shrishail Patil et al.[9] in their study, found that all cases of acute infarcts and 50% of subacute infarcts showed diffusion restriction. None of the chronic infarcts showed true restriction of diffusion. No signal abnormality was noted in 13% of acute infarcts on T2W images. 58% of infarcts were noted to be in MCA territory, 21% in PCA territory, 8% in ACA territory and 13% in vertebral artery and basilar artery territory.

The study included 7 infective conditions, of which 3 (42.86%) were tubercular granulomas, 3 (42.86%)

were NCC granulomas and 1 case (14.29%) of miliary tuberculosis. True restriction of diffusion was noted in 2 (28.57%) cases. This included 2 tubercular granulomas. Thus 28.57% of tubercular granulomas showed true diffusion restriction. T2 washout was seen in all 3 cases (100%) of NCC granulomas. In cerebral miliary tuberculosis lesions that showed increased diffusivity (hyperintense signal on ADC image). Several studies[7,8] have shown that DWI can differentiate necrotic tumors from abscesses, as both can show rim-like enhancement on post-contrast images. In Shrishail Patil et al.[9] study, 100% of cases of abscess showed true diffusion restriction. The cystic or necrotic component of none of the tumors included in this study showed restricted diffusion. According to V. Vishwas Chakra et al.[10], infective conditions (15 in total) were tubercular granulomas 6 (40%), Neurocysticercosis (NCC) granulomas 3 (20%), abscesses 3 (20%), extradural empyemas 2 (13.3%) and HSV encephalitis 1 (6.7%). True restriction of diffusion was noted in 7 (46.66%) cases.

Diffusion-weighted MR plays a key role in differentiating arachnoid from epidermoid cysts. Schaefer et al. showed that conventional MR could not 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 the brain parenchyma, while arachnoid cysts had ADC values similar to CSF. Tadeusz et al.[3] concluded that most meningiomas are isointense on DWI. Only a few may show restricted diffusion depending on their cellularity. In their study, 23% of meningiomas showed restricted diffusion. This study had approximately similar results.

CONCLUSION

Diffusion-weighted MRI is a valuable technique that provides unique information about the physiological state of brain tissue. 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. Diffusion-weighted MRI has been proven to be of excellent use in the characterization of infarcts and in the detection of acute infarcts. It is especially useful in the initial few hours of the ischemic insult when conventional MR sequences may be inconclusive and may not detect the Infarct. Thus, DW MRI helps in differentiating and characterizing various intracranial lesions.

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