EVALUATION OF INTRACRANIAL LESIONS BY DIFFUSION WEIGHTED IMAGING

Shrishail Patil¹, Shivanand S. Melkundi², Govinda Raju B. T³

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ABSTRACT: Diffusion weighted imaging (DWI) is a specialized magnetic resonance imaging technique that depends on the random movement of water molecules within and between the intracellular and extracellular spaces. Regions with restricted mobility of water molecules yield a greater DW-MRI signal and appear bright. In apparent diffusion coefficient (ADC) maps, regions that contain high water mobility appear bright. **PURPOSE:** The objectives of the study were to describe the imaging characteristics of intra cranial lesions on DWI. **MATERIALS AND METHODS:** A descriptive MR Study was undertaken in 115 patients detected to have intracranial lesions. In all these patients the DWI findings were noted. **RESULTS:** In this study all cases (100%) of acute infarcts showed true diffusion restriction. 13% of acute infarcts showed no signal change on T2W images. The rest were hyperintense on T2WI. 50% of sub-acute infarcts and none of the chronic infarcts showed diffusion restriction. All cases of subacute and chronic infarcts were hyperintense on T2WI. 100% of cases of HII showed restricted diffusion while only 75% of them showed abnormal signal on T2WI All cases of abscesses showed diffusion restriction. Extradural empyema showed restricted diffusion. 40% cases of glioblastoma multiforme showed true restricted diffusion while none of the low grade gliomas or anaplastic astrocytomas showed diffusion restriction. Diffusion restriction was also noted in 75% of medulloblastomas and 50% of lymphomas. Among extra axial tumors, 33% of meningiomas showed diffusion restriction. All cases of arachnoid cysts showed low signal on DWI while epidermoid cysts showed restricted diffusion. Demyelination and PRES did not show restricted diffusion. **CONCLUSION:** DWI is a highly sensitive technique in the detection of acute infarcts and in Characterizing infarcts as acute, subacute and chronic. DWI is a sensitive modality for detecting HII and shows the extent of involvement better than T2WI. Presence of diffusion restriction is a useful method of differentiating abscesses from necrotic or cystic neoplasms. Highly cellular tumors such as lymphomas, medulloblastoma and meningioma may show restricted diffusion. Arachnoid cysts can be differentiated from epidermoid cysts by the presence of low signal on DWI.

KEYWORDS: Diffusion Weighted Imaging, ADC, PRES.

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. Acute cerebral infarct results in anoxic injury to the cell membrane. This results in reduced movement of water molecules between extra and intracellular compartments.

Thus the earliest imaging feature of stroke is hyper intensity on DWI. ADC values vary with the age of the ischemic stroke, a fact that can affect the analysis of clinical cases. In the first few hours after onset of ischemia, water diffusion decreases rapidly. After about 24 hours it begins to rise and reaches normal values by 5 to 7 days. After about two weeks diffusion typically increases within the territory of the infarct.¹

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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 lesions on diffusion weighted images. The signal characteristics of these lesions on ADC images and T2 FLAIR images will also be described.

OBJECTIVES: The objectives of the dissertation titled “Diffusion Weighted Magnetic Resonance Imaging features of intracranial lesions” are as follows:

1. To describe the features of intracranial lesions on Diffusion Weighted Imaging.
2. To compare the Diffusion Weighted Imaging features of these lesions with ADC and T2 FLAIR images so as to help differentiate among them.

MATERIALS AND METHODS: The study was performed at the Department of Radio diagnosis Basaveshwar Hospital, Kalaburagi, to describe the features of intracranial lesions on diffusion weighted imaging and to compare these features with ADC and T2 FLAIR images.

Source of Data: The source of data for this study is patients referred to the Department of Radiodiagnosis, Basaveshwar Hospital, Kalaburagi for MRI brain with diffusion weighted imaging. This consists of a study of 115 patients with intracranial 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. This dissertation evaluates the diffusion weighted imaging characteristics of intracranial lesions that were detected in these patients.

Inclusion Criteria: The criteria for inclusion of the patients in the study included those patients who were clinically referred for diffusion weighted MRI of the brain and were detected to have any of the following:

1. Infarction and hypoxic ischemic injury.
2. Infective conditions.
3. Tumors—extra axial and intra axial.
4. Demyelination.
5. Metabolic or toxic insults to the brain.
6. Degenerative disorders.

Exclusion Criteria: Patients who are detected to have intracranial bleed were excluded from the study.

Data Acquisition: Patients referred for diffusion weighted MRI of the brain, underwent the examination after contraindications for MRI were excluded and consent was taken. All the MRI scans in this study were performed using 1.5 T MRI scanner (Philips achieve 1.5T).

MRI Protocol:

MRI protocol consisted of the following:

- A head coil was used.
- Axial diffusion weighted images of the brain.
- Sagittal T1W images of the brain.
- Axial T2W FLAIR images of the brain.
- ADC images were reconstructed from the diffusion weighted image.

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RESULTS: Of the 115 patients studied, 31 (41%) were females and 84 (59%) were males. The mean age among females was 50 years and the mean age among males was 44 years.

Spectrum of Intracranial Lesions: Of the total cases included in this study, 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%). These included 1 case of adrenoleucodystrophy, 1 periventricular leucomalacia, and 2 posterior reversible encephalopathy syndrome cases.

Imaging Characteristics of Intracranial Lesions: Of the 115 patients included in this study, 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. This constituted 29.4% of the cases showing increased diffusivity. 13 of these showed T2 washout, and 23 showed T2 shine through. Infarcts comprised the majority of lesions at 52 cases (45.2% of the total cases studied).

Of these acute infarcts constituted 30 cases (57.7%); 18(34.6%) were chronic infarcts and 4 (7.6%) were subacute infarcts. 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. Thus DWI not only helped detect all cases of acute infarcts but also proved to be a useful tool in categorizing the infarcts as acute, chronic and subacute infarcts.

Among intra axial tumors true restriction was noted in 6 cases. 40% of glioblastoma multiforme showed true diffusion restriction. None of the low grade gliomas or anaplastic astrocytomas showed diffusion restriction. Thus DWI may help in grading gliomas. DWI also provides information of the cellularity of tumors. 75% of medulloblastomas and 50% of lymphomas showed diffusion restriction. These tumors are known to have high cellularity.

All cases of intracerebral abscesses showed true diffusion restriction. This feature of abscesses on DWI has been shown to help differentiate them from cystic or necrotic brain tumors. The cystic or necrotic component of none of the brain tumors included in this study showed diffusion restriction. All cases of arachnoid cysts seen in this study had low signal on DWI.

This helps differentiate them from epidermoid cysts which were seen to have higher signal on DWI. 33% of meningiomas showed restricted diffusion in this study likely reflecting their high cellularity. All cases of HII showed true diffusion restriction. 25% of these cases showed no signal change on T2WI. Also the extent of abnormality was noted to be more on DWI than on T2WI. Thus DWI is a more sensitive imaging technique than T2WI in the evaluation of HII. Two cases of extradural empyemas seen in this study showed restricted diffusion similar to abscesses. Hypertensive encephalopathy and demyelination did not show restricted diffusion reflecting absence of cytotoxic edema in these conditions.

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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.²

In this study 115 patients with intracranial lesions detected on DW MRI of the brain were included. It was found that DW MRI provides adjunctive information for intracranial lesions including stroke, neoplasms, infections, hypoxic ischemic encephalopathy and extra axial lesions in conjunction with conventional MRI.

Infarcts and HII:

Infarcts: The sensitivity and specificity of DWI in the detection of acute ischemia is 100%. The difference in sensitivity of DWI and conventional MRI sequences is more in the initial time period and decreases as time progresses. Results of this study are correlated with a study done by Gonzalez et al.³ who concluded that DWI is superior to conventional MRI in the diagnosis and characterization of acute infarct.

In this study restricted diffusion was noted in 100% of acute infarcts. In 13% of acute infarcts, no change was noted on T2WI. Thus DWI was noted to be superior to T2WI in detection of acute infarcts. In subacute infarcts and chronic infarcts, abnormal signal was noted on T2WI and on DWI in all patients. Thus there was no difference in their sensitivity for later stages of infarcts.

Rima K et al.² and showed that restricted diffusion is present in all patients on DW MR studies obtained within 24 hours of the onset of symptoms, and in 94% of patients scanned after 2 weeks after ictus. In this study subacute infarcts were defined as patients in whom imaging was performed between 2 and 14 days after symptom onset.⁴ True diffusion restriction was noted in 50 % of patients with subacute infarcts. The other 50% showed T2 shine through. In this study 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.

This is comparable to a study done by Van Der Zwan et al.⁵ 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.⁶

In this study T2 shine through was noted in 55.5% of chronic infarcts and cystic encephalomalacia was noted in 44.4%.

Hypoxic ischemic injury Diffusion-weighted imaging has proved to be more sensitive than conventional MR imaging sequences for early detection of hypoxic ischemic brain injury. Fu JH et al.⁷ compared conventional MRI sequences to DWI in the evaluation of HII and found that DWI showed abnormal high signal intensity in the brain in patients in whom the conventional MR sequences were initially normal. Schaefer et al.⁶ concluded that HII lesions not seen on routine MR images are identified on DW MR images. When lesions are identified on conventional images, lesion conspicuity is increased and lesion extent is seen to be larger on DW MR Images.

All cases of neonatal HII included in this study showed true diffusion restriction. In 25% of cases there was no abnormality on T2 FLAIR images. The extent of abnormal signal was much more in the remaining 75% of cases on DWI, than that showed by T2W images.

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Infections: 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.⁸ 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 none of the tumors included in this study showed restricted diffusion.

In 33.3% of the tubercular granulomas observed in this study, diffusion restriction was noted, probably denoting presence of necrosis. 50% of tubercular granulomas and 100% of NCC granulomas could not be detected on DWI alone and needed ADC and T2W images for lesion detection probably due to the poor spatial resolution of diffusion weighted imaging.

All two cases (100%) of extradural empyemas noted in this study showed true diffusion Restriction. The thick nature of this collection causes reduced water diffusivity similar to abscesses.

Tumors: Intra Axial Tumors: MR imaging is the most sensitive method of detecting tumors of the brain. It is however not specific enough to determine the histological nature of most tumors. DWI can differentiate between tumor and infection and can provide information about the cellularity of tumors thereby helping in characterization and grading of tumors.⁹ Cruz CH et al.¹⁰ showed that highly cellular tumors such as high grade gliomas and lymphomas can have low ADC values and show restricted diffusion. It was also shown that medulloblastomas may be differentiated from other pediatric brain tumors by presence of diffusion restriction. The solid portion of hemangioblastomas has high ADC values due to their rich vascular spaces.

The findings of this study were similar. In this study, 40% of GBM, 75% of medulloblastomas and 50% of lymphomas showed true diffusion restriction. None of the low grade gliomas or anaplastic astrocytomas showed restricted diffusion. The single case of hemangioblastoma seen in this study showed high signal on ADC images in its solid component suggesting high water diffusivity.

Extra Axial Tumors: Diffusion weighted MR plays a key role in differentiating arachnoid from epidermoid cysts. Schaefer et al.⁶ 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.¹⁰ in which epidermoid cysts had ADC values similar to brain parenchyma while arachnoid cysts had ADC values similar to CSF.

In this study all 5 cases of arachnoid cysts had signal similar to CSF on DWI and ADC images. The single case of epidermoid cyst noted in this study had restricted diffusion. Tadeusz et al,¹¹ and Cruz et al,¹⁰ concluded that most meningiomas are isointense on DWI. Only few may show restricted diffusion depending on their cellularity. In their study 23% of meningiomas showed restricted diffusion. This study had similar results with 33% of meningiomas showing true diffusion restriction. Schwannomas show high signal on ADC images with no restricted diffusion reflecting lack of high cellularity.

Demyelination: Most demyelination plaques which may or may not be part of multiple sclerosis have been shown to have increased ADC values. It is very rare for a plaque to show restricted diffusion. Studies done by Christiansen P et al,¹² and Larsson H et al,¹³ have shown that most foci of demyelination

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do not show restricted diffusion. The four cases of demyelination seen in this study did not show restricted diffusion and had increased signal on T2 FLAIR images.

Others: Schwartz et al,¹⁴ showed that the edema of hypertensive encephalopathy is of vasogenic type. The results of this study are similar. None of the cases of PRES seen in this study had features of restricted diffusion. No signal change was noted in periventricular leucomalacia seen in this study, while the single case of adrenoleucodystrophy showed features of vasogenic edema.

CONCLUSION: Diffusion weighted MRI is a valuable technique that provides unique information about the physiological state of brain tissue. The current study comprised 115 patients evaluated in Basaveshwar Hospital Kalaburagi, who underwent DW MRI of the brain when they were referred for suspected intracranial lesions. All the MRI scans in this study were performed using 1.5T MRI scanner (Philips Achieva;).

Many different intracranial 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.

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. In the setting of multiple infarcts it helps detect the acute ones and is helpful in differentiating acute, subacute and chronic infarcts. Thus diffusion weighted MR imaging has to be included in any standard imaging protocol for stroke patients.

In the evaluation of HII, diffusion weighted MRI is a highly sensitive tool and is superior to conventional MR sequences in evaluating the extent of brain injury. 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. In the evaluation of extra axial collections DWI is useful in the evaluation of empyemas as they show restricted diffusion.

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. DWI also helps identify medulloblastomas by showing true restriction in these lesions.

In contrast other posterior fossa lesions such as hemangioblastomas and pilocytic astrocytomas do not show true restriction. Lymphomas may also show restricted diffusion due to their high cellularity. 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. Among extra axial tumors, restricted diffusion has been noted in meningiomas. There is no restriction of diffusion in schwannomas.

True restriction is not noted in majority of cases of demyelination. Instead high signal is noted on ADC images in most of these cases. Hypertensive encephalopathy is characterized by vasogenic edema. Hence there is no restriction of diffusion in these cases.

Thus DW MRI helps in differentiating and characterizing intracranial lesions.

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Intra cranial lesion	Age range								Total
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	
Abscess		1	1	1					3
ADEM	1								1
Acute infarct					4	11	14	1	30
Adrenoleucodystrophy	1								1
Anaplastic Astrocytoma				1	1				2
Arachnoid Cyst		2	2	1					5
Chronic infarct					1	5	7	5	18
Demyelination toxic				1					1
Epidermoid cyst				1					1
Extradural empyema			1	1					2
GBM						2	3		5
Hemangioblastoma					1				1
HSV encephalitis			1						1
Low grade glioma		1		3					4
Lymphoma						1	1		2
Medulloblastoma		4							4
Meningioma			1	2	5	1			9
Multiple sclerosis				1	1				2

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NCC granuloma			1	2					3
PVL	1								1
Pilocytic astrocytoma	1								1
PRES		1	1						2
Preterm HII	3								3
Profound term HII	1								1
Schwannoma				1		1			2
Subacute infarct					2	2			4
TB granuloma	1	1	2	1	1				6
TOTAL	9	10	10	16	16	23	25	6	115

Table 1: Age and Type Wise Distribution of Intracranial Lesions

Table 2: Age Distribution

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Table 3: Types of Intracranial lesions

Table 4: Intra-axial

Table 5: Extra-axial

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AUTHORS:

1. Shrishail Patil
2. Shivanand S. Melkundi
3. Govinda Raju B. T.

PARTICULARS OF CONTRIBUTORS:

1. Professor, Department of Radiology, Mahadevappa Rampure Medical College, Gulbarga.
2. Professor, Department of Radiology, Mahadevappa Rampure Medical College, Gulbarga.
3. Post Graduate, Department of Radiology, Mahadevappa Rampure Medical College, Gulbarga.

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NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Shrishail Patil,
Professor,
Department of Radiology,
Mahadevappa Rampure Medical College,
Gulbarga.
E-mail: mailtopatilss@rediffmail.com

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