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Original Research Article

Role of diffusion weighted magnetic resonance imaging of intra and extra axial intracranial lesions

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ABSTRACT

Background: Diffusion weighted imaging (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 sequence in many others.
Methods: The present study was conducted in the Department of Radiology, Dr. S. N. Medical College, Jodhpur, Rajasthan. Participants after understanding the study protocol and procedure, were asked to give their written consent for the study.
Results: In the study group of 115 patients (41%) were females and (59%) males. Infarcts comprised 45.2% of the total cases out of these acute infarcts constituted 30 cases (57.7%); 18 (34.6%) 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. Among intra axial tumours 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. 75% of medulloblastomas and 50% of lymphomas showed diffusion restriction. All cases of intracerebral abscesses showed true diffusion restriction. The cystic or necrotic component of none of the brain tumours included in this study showed diffusion restriction. All cases of arachnoid cysts seen in this study had low 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. Two cases of extradural empyema seen in this study showed restricted diffusion similar to abscesses. Hypertensive encephalopathy and demyelination did not show restricted diffusion reflecting absence of cytotoxic oedema in these conditions.
Conclusions: DW MRI helps in differentiating and characterizing intracranial lesions.

Keywords: ADC (Apparent diffusion coefficient), DWI, Intracranial lesions, MRI (Magnetic resonance imaging), T1W (T1 weighted), T2W (T2 weighted)

INTRODUCTION

Diffusion weighted imaging (DWI) is a technique that assesses local environment at the cellular level to determine changes in the random movement of water protons. Whereas DWI is most often used to identify acute arterial ischemia, other processes that interfere with or restrict the movement of water can cause notable changes on DWI, including neoplastic lesions, encephalitis, pyogenic abscesses and occasional

demyelinating diseases. Reduced diffusion can be seen in highly cellular tumors such as lymphoma, meningioma and glioblastoma. Several reports have suggested an inverse correlation between ADC value and glioma grade 2 to grade 4 astrocytoma.[1]

The signal intensity of gliomas on DWI is variable (hyper, iso or hypo intense), and a subtle hyper intensity is a common nonspecific finding. Tumor cellularity is probably a major determinant of ADC values of brain tumors, although probably not the only one. ADC values cannot be used in individual cases to differentiate glioma types reliably (the ADC values of patients with grade 2 astrocytoma and glioblastoma overlap). The ADC values of solid gliomas, metastasis and meningioma were in the same range. In cases of lymphomas, however there was a good contrast with the white matter, with strongly reduced ADC values. Further studies are needed to define clearly the ability of DWI to help differentiate various brain tumors and to help grade gliomas.[2]

DWI is useful in providing a greater degree of confidence in distinguishing brain abscesses from cystic or necrotic brain tumors than conventional MRI.[3] Thus, it may increase the diagnostic accuracy when combined with other sequences. Likewise, in Creutzfeldt-Jakob disease, DW imaging helps differentiate from infarct by showing persistent restricted diffusion.[4]

Thus, diffusion weighted imaging (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 sequence in many others.

METHODS

The study was conducted in the Department of Radio diagnosis, Dr. S. N. Medical College and associated group of hospitals, Jodhpur. Imaging was done with Philips 1.5 tesla magnetic resonance imaging equipment for one year from 2013 to 2014.

Inclusion criteria

All patients with diffusion weighted magnetic resonance imaging reference for infarction, hypoxic ischemic injury, infective condition, tumors, demyelination, metabolic and toxic insult to brain, Degenerative disorder irrespective of age and sex were included in the study.

Exclusion criteria

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

Patients underwent the examination after contraindications for MRI were excluded and consent was taken. All the MRI scans in this study were performed using 1.5T MRI scanner. 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 images.

Table 1: MRI protocols.

	DWI	T2-FLAIR axial	T1-FLAIR sagittal
TE	5000	8002	2060
TE	80	86	20
TI		2000	650
Matrix	128*192	256*320	224*384
No. of excitations	2	1	1
Thickness	5 mm	5 mm	5 mm
Section spacing	1.5 mm	1.5 mm	1.5 mm
FOV	24*30	24*24	24*24
Imaging time	45 sec	1min 25 sec	1 min. 25 sec

Data evaluation

The observations of these patients were compiled and analyzed. All statistical analyses were conducted using the SPSS statistical package (version 16.0).

RESULTS

The present study was carried out to describe imaging characteristics of various intracranial lesions on DWI and to compare them with ADC and T2 FLAIR images.

Age wise distribution of patients

The age of the patients with intra cranial lesions ranged from 3 days to 78 years with a mean of 43.97±2.04. The patients involved in the study were divided into 7 age groups viz. 0-10 years, 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years and 61-70 years. There were nine patients (7.8%) in 1-10-year age group, ten (8.6%) in 11-20-year age group, ten (8.6%) in 21-30-year age group, sixteen (13.9%) in 31-40-year age group, sixteen (13.9%) in 41-50 year age group, twenty three (20%) in 51-60 year age group, twenty five (21.7%) in 61-70 year age group, six (5.2%) in 71-80 year age group as given in Table 2.

In the present study 31 (41%) were females and 84 (59%) males. The mean age among females was 50 years and in males was 44 years. In the present study, 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%). These included 1 case of adrenoleucodystrophy, 1 periventricular leukomalacia, and 2 posterior reversible encephalopathy syndrome (PRES) cases.

Table 2: Age wise distribution.

Intra cranial lesion	Age (years) range								Total
	0-10	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
Adrenoleucodystropy	1								1
Anaplastic astrocytomas				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
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

In present cohort, 82 cases (71.2%) showed hyper intensity on DWI of which true restriction (hyper intense on DWI and hypo intense 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 hypo intensity on ADC images. All of these were hyper intense on DW images. 13 patients (11.3%) showed T2 washout (hyper intense 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 (hyper intense signal on ADC image). Of these 15 (13%) were hypo intense 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 constituted 52 cases (45.2%) of the total cases in this study. Of this 30 (57.7%) were acute infarcts, 18 (34.6%) were chronic infarcts and 4 (7.6%) were subacute infarcts. The age group of patients with infarcts ranged from 43 to 78 years with a mean age of 60 years. There were 13 (25%) females and 39 (75%) males among these cases. In 30 cases (58%) the infarcts were in MCA territory, in 4 cases (8%) they were in ACA territory, in 11 cases (21%) the infarcts were in PCA territory and in 7 cases (13%) they were in basilar artery and vertebral artery territory. All 30 cases (100%) of acute infarcts showed true diffusion restriction with hyper intensity on DWI and hypo intensity on ADC images. Of these, 26 cases (86.66%) showed hyper intensity on T2W images. The remaining 4 cases (13%) showed no signal change on T2W images.

Of the 18 cases of chronic infarcts, ADC signal was increased in all, suggesting increased water diffusivity. In 8 cases (44.44%), there was hypo intensity on DWI and T2 FLAIR images with hyper intensity on ADC images indicating encephalomalacia. T2 shine through was noted in 10 cases (55.55%). None of the cases showed T2 washout. Out of 4 cases of subacute infarcts, 2 (50%) showed true restriction and 2 (50%) showed T2 shine through.

Four cases of hypoxic ischemic injury were included in this study, age range of 3 days to 15 days. Three cases were preterm neonates and one was a term neonate. All four cases showed true diffusion restriction. 3 of four cases (75%) showed hyper intensity on T2 FLAIR images, and 1 (25%) did not show any change on T2 FLAIR images. The extent of abnormality was noted to be more on DW and ADC images than on T2 FLAIR images.

In study major, 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. This included 2 tubercular granulomas 3 abscesses and 2 extradural empyemas. Thus 33.33% of tubercular granulomas, 100% of abscesses and 100% of extradural empyemas showed true diffusion restriction. T2 washout was seen in all 3 cases (100%) of NCC granulomas and 3 cases (50%) of tubercular granulomas. T2 shine through was seen in 1 case of tubercular granuloma and one case of HSV encephalitis.

There were 19 cases of intra axial tumors with age ranging from 10 to 68 years with 5 females and 14 males. This included 2 cases of anaplastic astrocytoma, 5 cases of glioblastoma multiforme, 1 hemangioblastoma, 4 low grade gliomas, 4 medulloblastomas, 1 pilocytic astrocytoma, and two cases of lymphomas. 6 cases (31.6%) showed true diffusion restriction. Of these 2 were GBM, 3 were medulloblastomas, and one was lymphoma. Thus 40% of GBM, 75% of medulloblastomas, and 50% of lymphomas showed true restriction of diffusion.

T2 shine through was noted in 8 cases (42.1%). This included all 2 cases of anaplastic astrocytomas, 3 cases (60%) of GBM, 2 cases (50%) of low grade gliomas and 1 (50%) case of lymphoma. T2 washout was seen in one case of hemangioblastoma and 2 cases (50%) of low grade gliomas.

17 cases of extra axial tumors with an age range of 14 to 52 years, mean 36 years were included in this study. Of these 6 were females and 11 were males. These were 5 cases of arachnoid cysts, 1 epidermoid cyst, 9 cases of meningiomas and 2 cases of schwannomas. True restricted diffusion was noted in 4 cases (23.52%). This included the single case of epidermoid cyst and 3 cases (33.3%) of meningiomas. In one case of meningioma, T2 shine through was noted. In 6 (66.6%) cases of meningiomas, T2 FLAIR showed iso to hypo intense signal probably due to high cellularity and presence of calcification. 1 case (50%) of schwannoma showed T2 washout.

Out of four cases of demyelination, two (50%) were multiple sclerosis, one was a case of toxic demyelination and one was a case of ADEM. All the lesions showed hyper intensity on T2 FLAIR images. True restriction of diffusion was not noted in any of the cases. T2 washout was seen in one case of multiple sclerosis (50%) and in toxic demyelination. No change was noted on DWI or ADC images in one case (50%) of multiple sclerosis and in ADEM.

Miscellaneous other lesions like 1 case of adrenoleucodystrophy, 1 case of periventricular leukomalacia and 2 cases of posterior reversible encephalopathy syndrome were detected. All the lesions showed hyper intensity on T2 FLAIR images. True restriction of diffusion was not noted in any of the cases. T2 washout was seen in one case of PRES. No change was noted on DWI or ADC images in one case of PRES. T2 shine through was noted in adrenoleucodystrophy.

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.[5] In this study, 115 patients with intracranial lesions detected on DW MRI of the brain were included.

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 our study are similar with a study done by Gonzalez et al who concluded that DWI is superior to conventional MRI in the diagnosis and characterization of acute infarct.[6] 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 showed that restricted diffusion is present in all patients on DWMR studies obtained within 24 hours of the onset of symptoms, and in 94% of patients scanned after 2 weeks after ictus.[5] In this study, subacute infarcts were defined as patients in

whom imaging was performed between 2 and 14 days after symptom onset. Schwartz R et al, 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 Zwan VD et al, which showed that MCA territory is the most common site for infarcts and ACA territory is the least common among major arterial territories.[8]

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 Schaefer PW et al.[9] In the present study T2 shine through was noted in 55.5% of chronic infarcts and cystic encephalomalacia was noted in 44.4%.

Hypoxic ischemic injury

Fu JH et al, 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.[10] Schaefer et al, concluded that HII lesions not seen on routine MR images are identified on DW MR Images.[9] 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.

Infections

Chang et al, 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 the present 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

In the present 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. DWI can differentiate between tumor and infection and can provide information about the cellularity of tumors thereby helping in characterization and grading of tumors. Cruz CH et al, showed that highly cellular tumors such as high-grade gliomas and lymphomas can have low ADC values and show restricted diffusion.[11] 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.

Extra axial tumors

Schaefer et al, showed that conventional MR cannot be reliably used to differentiate these two lesions as both have CSF like signal intensity on conventional MR sequences.[9] This was also demonstrated in a study by Cruz et al, in which epidermoid cysts had ADC values similar to brain parenchyma while arachnoid cysts had ADC values similar to CSF.[11] In the present 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 and Cruz et al concluded that most meningiomas are isointense on DWI.[11,12] 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

Four cases of demyelination seen in this study did not show restricted diffusion and had increased signal on T2 FLAIR images. Studies done by Christiansen P et al and Larsson H et al, have shown that most foci of demyelination do not show restricted diffusion.[13-14]

Others

Schwartz et al, showed that the edema of hypertensive encephalopathy is of vasogenic type.[7] 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 leukomalacia 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. 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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