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Role of DWI in the Evaluation of Intracranial Lesions

Dr Aditya Verma[1], Dr Mohd Zahid Batt[2], Dr Abhinav Chetan[3]

1. Introduction

Diffusion weighted imaging is a specialized magnetic resonance imaging technique that depends upon the random movement of water molecules within and between the extracellular and intracellular spaces. It provides microscopic information from water protons that is not possible with conventional MRI imaging. Regions with restricted water mobility yield a higher signal and appear bright on DW imaging(**Haaga JR et al 2009).** Apparent diffusion coefficient (ADC) is a quantitative parameter calculated from DWI that combines the effect of capillary perfusion and water diffusion. . ADC value is calculated for each pixel of the image and is displayed as a parametric map. DWI is most applicable in the tissues which are dominated by isotropic water movement like grey matter in cerebral cortex and major brain nuclei.It has been used to study the normal brain and various diseases such as ischemia,tumors,epilepsy and white matter disorders **(Chenevert et al 1990 and Rowley HA et al 1999).** DWI provides useful information, increasing the sensitivity of MRI as a diagnostic tool, narrowing the differential diagnosis, providing the prognostic information, aiding the treatment planning and evaluating the response to treatment.

2. Material and Methods

The study was conducted on a total of 93 eligible patients who were referred to the Department of Radiodiagnosis and Imaging for MRI evaluation. Informed and written consent was taken from the patients prior to exam. All the cases had undergone MRI scan **using SIEMENS MAGNETOM SYMPHONY 1.5 TESLA TIM (SIEMENS HEALTHCARE, GERMANY).** 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

Detailed history regarding the onset, duration and presentation of the neurological signs and symptoms was recorded. A short neurological examination was performed to correlate clinical and imaging finding. In all patients detected to have intracranial lesions on MRI of the brain, DWI findings were noted and correlated with ADC and T2 FLAIR and characterized. Diffusion weighted imaging was followed by intravenous contrast study on T1W SE sequence using Gadolinium DTPA. The dose of contrast was 0.2 mmol /kg body weight.

3. Observations and Results

Table 1: Spectrum of intracranial lesions.

Type of lesion	No. of cases	Percentage
Infarcts	33	35.5
Intracranial hemorrhage	5	5.4
Infections	18	19.4
Tumors	18	19.4
Demyelination(MS)	3	3.2
Metabolic	2	2.2
Congenital	3	3.2
Hypoxic ischemic injury	5	5.4
Miscellaneous	6	6.5

Table 4: Symptom wise distribution of the patients

Symptoms	No. of patients
Seizures	20
Headache	10
Weakness	22
LOC	11
Altered sensorium	8
Hypotonia	7
Diminution of vision	4
Memory	5
Vertigo	2
Slurred speech	2
Ataxia	1
Hallucination	1

Table 3: Territorial distribution of infarct cases in our study.

Territory	No. of cases
ACA	3
MCA	13
PCA	8
VABA	2
Multiple territories	3
Watershed	2
Venous	2

Table 4: Diffusion status of different stages of infarct

Stage of infarct	Total no. of cases	Restricted diffusion	T2 shine through	Free diffusion
Hyperacute	4	4	0	0
Acute	13	13	0	0
Subacute	11	5	3	3
Chronic	5	0	2	3

Hypoxic ischemic injury: -5 cases of hypoxic ischemic injury were included in this study with age range of 8 days to 24 days. 3 cases were preterm neonates and 2 were term neonate.

3 cases (60%) showed true restricted diffusion out of which 2 cases (66.6%) showed hyperintensity on T2 – FLAIR images while 1 case(33.3%) showed no signal change on T2-FLAIR images.

2 cases (40%) showed increased ADC values with increased diffusivity.

The extent of abnormality was noted to be more on DW and ADC images than on T2 FLAIR images.

Infections:- The study included total 18 cases of which 3 (16.7%) were NCC, 2(11.1%) were tubercular granulomas, 6(33.3%) were abscesses, 5 (27.8%) were HSV encephalitis and 2 (11.1%) were extraaxial empyemas.

True restricted diffusion was seen in 13 cases (72.2%). This included 6 abscesses, 2 extraaxial empyemas, 4 HSV encephalitis and 1 Tubercular granuloma. Thus 100% of abscess, 100% of empyema, 80% of HSV encephalitis and 50 % of Tubercular granuloma showed true restricted diffusion.

T2 Shine through was seen in 1 case (33.3%) of NCC and 1 case (20%) of HSV encephalitis.
T2 Blackout was seen in 1 case (33.3%) of NCC and 1 case (50%) of Tubercular granuloma.
T2 washout was seen in 1 case (33.3%) of NCC.

Tumors:- There were 20 cases of tumors in this study. Out of this 12 were intra axial tumors and 8 were extra axial tumors.

Table 8: Distribution of brain tumors based on location

Total no. of tumors	Intra axial tumors	Extra axial tumors
20	12	8

Intra axial tumors: - There were 12 cases(60%) of intra axial tumors. The age of the patients ranged from 8 years to 68 years with 7 males and 3 females. This included 1 case of lymphoma, 2 cases of low grade glioma, 1 case of pilocytic astrocytoma, 5 cases of GBM, 1 case of interventricular epidermoid cyst, 1 case of ependymoma and 1 case of metastasis.

6 cases (50%) showed true diffusion restriction. Of these, 3 were GBM, 1 was ependymoma, 1 was lymphoma and 1 was interventricular epidermoid cyst. Thus 60% of GBM, 100% of ependymoma, 100% of lymphoma and 100% of IV epidermoid cyst showed true restriction of diffusion.

ADC signal was increased with decreased DWI signal in 3 cases (25%) suggesting increased diffusivity. This included 1 case (50%) of low grade glioma, 1 case (100%) of pilocytic Astrocytoma and 1 case (100%) of metastasis. T2 shine through was seen in 3 cases (25%). This included 1 case (50%) of low grade glioma and 2 cases of GBM(40%).

Extra axial tumors: - 8 cases of extra axial tumors were included in this study with an age range of 20 to 75 years. Of these 7 were males and 1 female. These included 2 cases of arachnoid cysts, 2 cases of pituitary macroadenoma, 2 of meningioma, 1 of schwannoma and 1 case of clival chordoma.

True restricted diffusion was noted in 4 cases(50%). This included 2 cases of meningioma, 1 of Schwannoma and 1 of pituitary macroadenoma. Hence 100% cases of meningioma and schwannoma and 50% cases of pituitary macroadenoma showed diffusion restriction. 2 cases (100%) of Arachnoid cysts and 1 case (50%) of pituitary macroadenoma showed increased ADC signal with corresponding DWI hypointensity suggestive of increased diffusivity due to free diffusion. 1 case (100%) of clival chordoma showed normal signal on DWI and ADC and hyperintense signal on T2-FLAIR images.

Demyelination: -3 cases of demyelination were included in the study which compromised of 2 cases (66.6%) of multiple sclerosis and 1 of ADEM. None of these lesions showed restricted diffusion. 1 case (50%) of multiple sclerosis showed T2 washout and 1(50%) showed normal signal intensity on DWI and ADC and hyperintensity on on T2-FLAIR images. 1 case (100%) of ADEM showed T2 washout.

Intracranial hemorrhage:-5 cases of different evolutionary stages of hemorrhages were included in this study which comprised of 1 case (20%) of hyperacute, 2 cases(40%) of acute and 2 cases(40%) of subacute hemorrhages. Only one case (20%) showed restricted diffusion. It was the hemorrhage in hyperacute stage. Rest 4 cases(80%) of cases showed hypointense signal intensity on DWI,ADC and T2-FLAIR signals suggestive of T2 Black out.

Metabolic Encephalopathy: We included two cases of metabolic encephalopathy in our study. One was a case of hypoglycemic encephalopathy and other was hepatic encephalopathy. Both showed restricted diffusion and signal on DWI was more conspicuous than that on T2-FLAIR images.

Miscellaneous:- This group consisted of total 6 cases comprising of 1 case of limbic encephalitis, 1 of PRES, 1 of cortical laminar necrosis and 3 of post status epilepticus. 5(83%) of cases showed diffusion restriction barring one case of PRES which showed no change on DWI or ADC images and hyperintensity on T2- FLAIR images.

4. 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. The 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 tissues brain.

In this study 93 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.

In this study diffusion restriction was noted in 100% of hyperacute and acute infarcts. In 75% of hyperacute and 7.7% of acute infarcts, no change was noted on T2-FLAIR

images. Thus DWI was noted to be superior to T2-FLAIR sequences in the detection of acute infarcts.

In the subacute and chronic infarcts, abnormal signal was noted on T2-FLAIR and on DWI in all patients. Thus there was no difference in their sensitivity for later stages of infarcts.

Results of this study were correlated with a study done by **Gonsalez et al (38)** who concluded that DWI is superior to conventional MRI in the diagnosis and characterization of acute infarct.

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 (32)** 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(92)** concluded that HII lesions not seen on routine MR images are identified on DW MR images. When HII lesions were identified on conventional images, lesion conspicuity and lesion extent was seen to be larger with DW MR images. 60% of cases of HII in our study showed true diffusion restriction out of which 33.3% of cases showed no abnormality on T2-FLAIR images. The extent of abnormal signal was much more in the remaining 66.7% cases on DWI , than that showed by T2W images. In 40% of cases presenting later in their clinical course increased diffusivity (free diffusion) was seen due to cystic encephalomalacia.

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

Lai et al (20) have shown 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 abscesses from necrotic tumors. Also it helps in the evaluation of partially treated abscesses and to look for their recurrence.

In our 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. Hence our findings are consistent with Lai et al and other investigators like **Kim YJ et al (57)** and **Ebisu T et al(26).**

Our study included 5 cases of HSV encephalitis out of which 80% showed diffusion restriction and 20% showed T2 Shine through. Also one case (25%) showing diffusion restriction was having normal signal on T2-FLAIR images. Our findings correlated with those of **Renard D et al (86) and Tsuchiya K et al (108)** who found that DWI is more sensitive sequence in the acute-subacute stage of HSV encephalitis.

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. **Cruz CH(24) et al** showed that highly cellular tumors such as high grade gliomas and lymphomas can have low ADC values and show restricted diffusion. The findings of our study partly corroborated above findings and showed 60% of GBM, 100% of Lymphoma and 100% of meningioma showed true restricted diffusion. Our findings of 100% diffusion restriction in meningiomas is not consistent with **Fillipi CG et al (30)** who reported variable diffusion appearance of meningiomas on DWI.

Diffusion weighted MR plays a key role in differentiating arachnoid from epidermoid cysts. Our findings are consistent with **Schaefer et al(92)** who showed that conventional MR cannot be reliably used to differentiate these two lesions as both have CSF like signal intensity on conventional sequences. However on DWI epidermoid cyst shows restricted diffusion while arachnoid cyst shows CSF like density. This was also demonstrated by **Cruz et al(24),** in which epidermoid cysts had ADC values similar to brain parenchyma while arachnoid cysts had ADC values similar to CSF.

100% cases of metastasis and pilocytic astrocytoma, 50% cases of low grade glioma revealed free diffusion. 50% cases of low grade glioma revealed T2 shine through effect and hence free diffusion in our study.

Findings further correlated with the study done by **Al-Okaili A et al (5)** who reported that metastasis tend to demonstrate facilitated diffusion in the form of increased ADC signal.

In our study 50% cases of pituitary macroadenoma revealed true restricted diffusion and 50% showed increased ADC signal with hypointensity on DWI suggestive of increased diffusivity. Our findings correlated with study of **Pieralline A**,**et al (83)**,who reported variable appearance of pituitary macroadenoma on diffusion weighted imaging with a spectrum of ADC values depending on the consistency of the pituitary macrodenoma demonstrated postoperatively.

Demyelination:- Most demyelination plaques which may or may not be part of multiple sclerosis have shown to have increased ADC values. It is very rare for a plaque to show restricted diffusion. Studies done by **Christiansen P et al(23) and Larsson H et al (62)**have shown that most foci of demyelination do not show restricted diffusion. Our study is in conformity to these studies as none of the 3 cases of demyelination included in our study showed restricted diffusion.

Intracerebral hemorrhage: We studied 5 cases of intracerebral hemorrhage. One was hyperacute,two acute and 2 subacute. Hyperacute hemorrhage revealed brilliant DWI hyperintensity and ADC hypointensity similar to infarct and differentiation could only be made by susceptibility artifact hypointense rim and conventional sequences. Our findings correlated with quantitative analysis and qualitative study of **Atlas et al (8)** and **Silvera S et al(98),** respectively who reported low ADC values in intracellular stages of hemosiderin degradation. Two acute

and two subacute hemorrhages revealed T2 hypointense signal and were also hypointense on DWI and ADC sequences suggestive of T2 Black out described by **Silvera S et al (98).**

Metabolic encephalopathy:-Two cases one of hypoglycemic encephalopathy and other of hepatic encephalopathy showed true restricted diffusion and the signal was more conspicuous as compared to the conventional sequences. The findings correlated with the study done by **Kang EG et al (54),** who demonstrated that earliest finding in these cases is demonstrated on DWI with corresponding low signal on ADC.

5. Conclusion

This study showed that DWI is an invariably indispensible tool in the stable of MR sequences that can help extract additional information which is not available from the conventional MR sequence protocols thereby aiding optimum disease diagnosis aiding the radiologist as well the clinician in patient diagnosis and management.