Research Article

Signal intensity features of intracranial lesions on diffusion weighted magnetic resonance imaging

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Abstract

Introduction: Diffusion weighted imaging is an essential sequence to be included in any ptotocol for magnetic resonance imaging of the brain and therefore it is essential to study the signal intensity features of intracranial lesions in this sequence. **Aims:** To describe the signal intensities of intracranial lesions on diffusion weighted imaging and to compare this with apparent diffusion coefficient maps. **Methods and Materials:** Images of 115 patients who underwent magnetic resonance imaging at our hospital from March 2010 to March 2011 were prospectively studied. The signal intensities of various lesions on diffusion weighted images, apparent diffusion coefficient maps were studied. **Statistical analysis used:** Percentages of individual intra and extra cranial lesions that showed diffusion restriction, increased diffusivity or isointense signal relative to gray matter were calculated. **Results:** All cases of acute infarcts, hypoxic ischemic injury, abscesses and extradural empyemas showed diffusion restriction. 50% of subacute infarcts, 33% of tuberculomas, 40% of GBM, 75% of medulloblastomas, 33% of meningiomas, single case of epidermoid cyst and 50% of lymphomas showed true restriction of diffusion. The remaining cases showed increased diffusivity or intermediate signal intensity. **Conclusion:** Intracranial lesions show a varied appearance on diffusion weighted imaging and this sequence is an important tool in establishing an accurate diagnosis.

Keywords: Diffusion weighted imaging, Intra Axial, Extra Axial, Magnetic Resonance Imaging

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INTRODUCTION

Diffusion weighted imaging (DWI) is a sequence that determines changes in the random movement of water protons as a reflection of the local environment at the cellular level. Restricted diffusion appears as an area of increased signal on DWI and reduced signal on apparent diffusion coefficient (ADC) maps. While DWI has clearly established itself as the most sensitive technique in diagnosing acute stroke, it also plays a key role in staging subacute and chronic infarcts. It is a critical tool in differentiating abscesses from necrotic brain tumors and arachnoid cysts from epidermoid cysts. Restricted diffusion can be seen in tumors such as lymphoma, meningioma and glioblastoma. Several reports have reported an inverse correlation between ADC value and glioma grade[1,2]. However, there have been conflicting findings in other reports[3]. Therefore further studies are needed to clearly define this utility of DWI. Acute plaques of multiple sclerosis, on DWI, may show increased ADC due to vasogenic edema and myelin destruction with axonal preservation as reported in some studies[4] or decreased ADC due to intramyelinic edema as

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described in other studies[5]. Therefore this study could help throw further light on the matter. DWI may also play a role in evaluating many other conditions like encephalitis, granulomatous diseases and hypoxic ischemic injury (HII). In this backdrop of the wide range of applications of DWI in the brain, the objectives of this research were set to enable us to understand the appearances of various intracranial lesions on diffusion weighted images. The signal characteristics of these lesions on ADC images will also be described.

SUBJECTS AND METHODS

This was a prospective descriptive study. The source of data for this study is patients referred to the department of radiology at our hospital for MRI brain with diffusion weighted imaging from March 2010 to March 2011. A total of 115 patients of all ages and both sexes, with intracranial lesions detected on imaging were included in the study. The pathological conditions that were considered for the study were infarction and hypoxic ischemic injury, infective conditions, extra axial and intra axial tumors, demyelination, metabolic or toxic insults to the brain and degenerative disorders. Patients with intracranial bleed were excluded from the study. 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. All the MRI scans in this study were performed using 1.5 T MRI scanner (Signa HDxt; GE Medical systems). A head coil was used and the MRI protocol consisted of axial diffusion weighted images of the brain, sagittal T1W images of the brain, axial T2W FLAIR images of the brain, ADC images which were reconstructed from the diffusion weighted images (Table1).

RESULTS

Table 1: Imaging parameters

	DWI	T2 FLAIR axial	T1 FLAIR sagittal
TR	5000	8002	2060
TE	80	86	20
TI		2000	650
Matrix	128x192	256 X 320	224 x 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	24x30	24x24	24x24
Imaging time	45s	1 min 25s	1 min 25s

B value of 0 and 1000s/mm2 were used for diffusion weighting

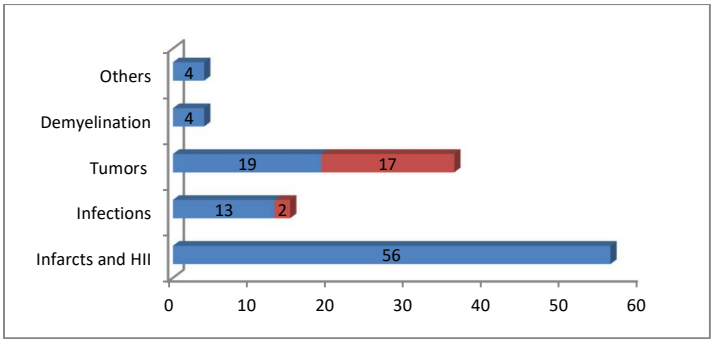

Figure 1: Chart showing intra axial and extra axial tumors seen in this study

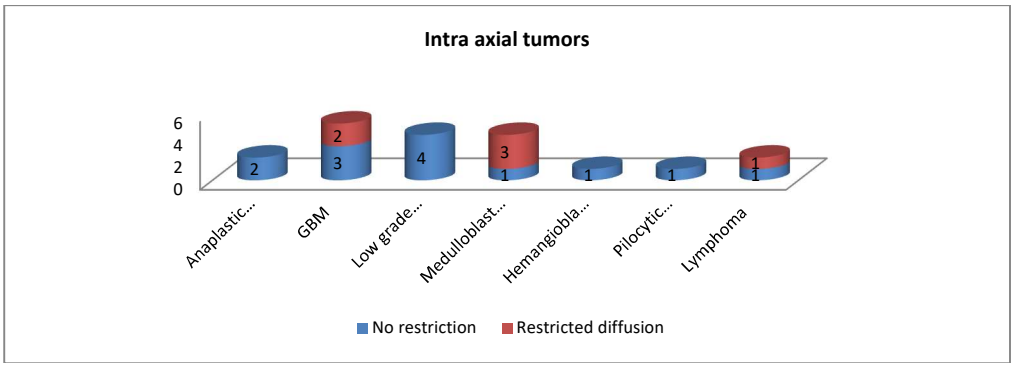

Figure 2: Chart showing diffusion weighted imaging characteristics of intra axial tumors

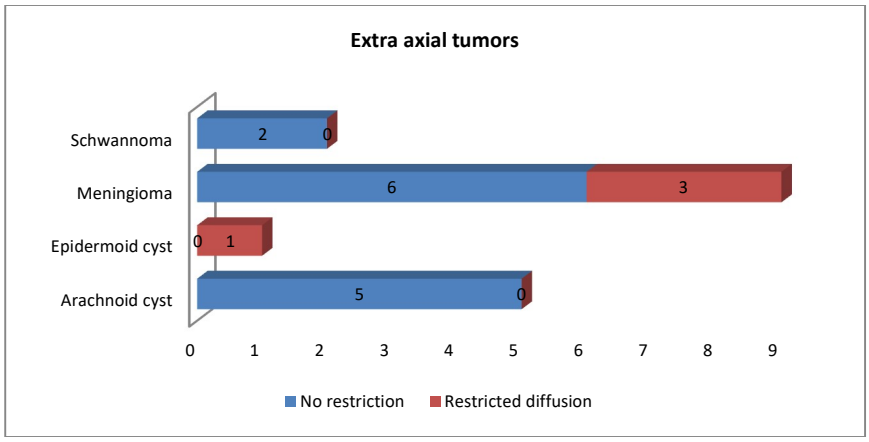

Figure 3: Chart showing diffusion weighted imaging characteristics of intra axial tumors

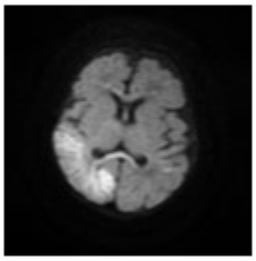

Figure 4a: Axial DWI image showing restricted diffusion in right parietal and occipital and splenium of corpus callosum in a term neonate with profound hypoxic ischemic injury.

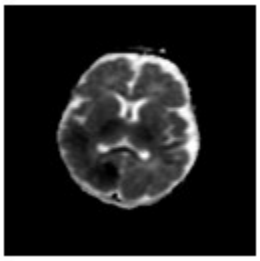

Figure 4b: Axial ADC image of the same patient as lobes figure 4a showing hypointense signal in right parietal and occipital lobes and splenium of corpus callosum.

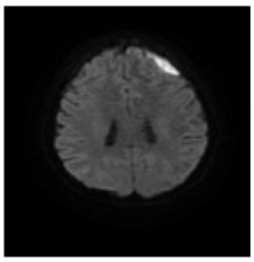

Figure 5a: Axial DWI image in a 27 year old male with fever, bifrontal headache and history of frontal sinusitis shows hyperintense, biconvex, extra-axial collection in left frontal region consistent with extradural empyema.

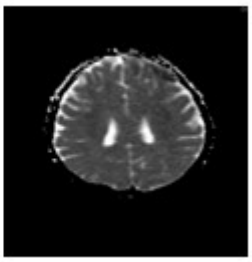

Figure 5b: Axial ADC image in the same patient as figure 5a showing hypointense signal in the collection r epresenting true diffusion restriction

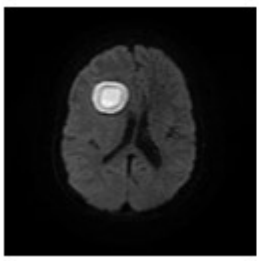

Figure 6a: Axial DWI image in a 15 year old male with headache, vomiting and high fever showing hyperintense lesion in the right frontal lobe suggestive of abscess

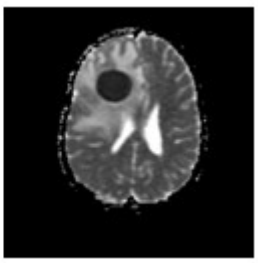

Figure 6b: Axial ADC image in the same patient as figure 6a showing hypointense signal in the lesion due to the thick, viscous nature of a cerebral abscess

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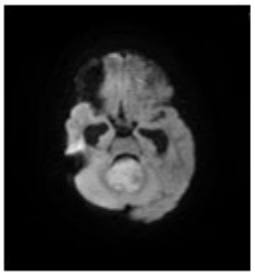

Figure 7a: Axial DWI image in a 10 year old child with headache and projectile vomiting showing a mass lesion with patchy diffusion hyperintensity

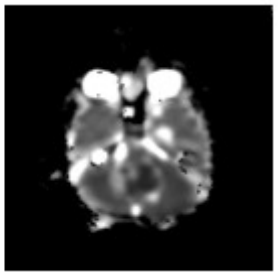

Figure 7b: Axial ADC image of the same patient as figure 7a showing hypointense signal in the lesion, indicating highly cellular neoplasm.

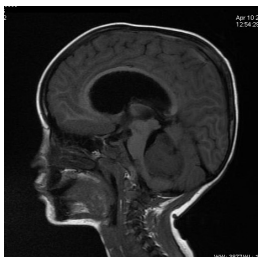

Figure 7c: Sagittal T1 weighted image of the same patient as figure 7a showing mass arising from the roof of the fourth ventricle suggestive of medulloblastoma

A total of 115 patients' MRI brain images were prospectively evaluated. The age of the patients with intra cranial lesions studied ranged from 3 days to 78 years. 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. 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 (Figure 1). All 30 cases (100%) of acute infarcts showed true diffusion restriction with hyperintensity on DWI and hypointensity on ADC images. Of these, 26 cases (86.66%) showed hyperintensity 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 hypointensity on DWI and T2 FLAIR images with hyperintensity on ADC images indicating encephalomalacic changes. 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. All four cases of hypoxic ischemic injury showed true diffusion restriction. 3 of four cases (75%) showed hyperintensity 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. The study included 15 infective conditions of which 6 (40%) were tubercular granulomas, 3 (20%) were neurocysticersosis (NCC) granulomas, 3 (20%) were abscesses, 2 (13.3%) were extradural empyemas and 1 case (6.7%) was herpes simplex virus (HSV) encephalitis. 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. Intra-axial tumors included 2 cases of anaplastic astrocytoma, 5 cases of glioblastoma multiforme (GBM), 1 hemangioblastoma, 4 low grade gliomas, 4 medulloblastomas, 1 pilocytic astrocytoma, and two cases of lymphomas. 6 cases (31.6%) of intra-axial tumors 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 (Figure2). 17 extra axial tumors seen in this study 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 hypointense signal probably due to high cellularity and presence of calcification. 1 case (50%) of schwannoma showed T2 washout. True restriction of diffusion was not noted in any of the cases of demyelination. 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. The single case of adrenoleucodystrophy, periventricular leucomalacia and 2 cases of posterior reversible encephalopathy syndrome (PRES) showed hyperintensity 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. In this study DWI was noted to be superior to T2WI in detection of acute infarcts with a sensitivity of 100%. In subacute infarcts and chronic infarcts, abnormal signal was noted on T2WI and on DWI in all patients. This study correlates with that of Lansberg *et al*[6] and demonstrates the capability of DWI in staging brain infarcts. All cases of neonatal HII included in this study showed true diffusion restriction whereas 25% of cases showed no abnormality on T2 FLAIR images. The extent of abnormal signal was also much more on DWI, than that on T2 FLAIR images. Schaefer *et al*[7] made similar conclusions in their study. 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. Desprechins *et al*[8] showed the superiority of DWI in differentiating abscesses from necrotic tumors as seen in this study. 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. 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. This is similar to the studies done by Sugahara *et al*[1] and Gauvain *et al*[2] in demonstrating diffusion restriction in tumors with higher nucleus to cytoplasm ratio. According to Filippi *et al*[9] most meningiomas do not show diffusion restriction. This study had similar findings with 33% of meningiomas showing true diffusion restriction. 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. As demonstrated by Tsuruda *et al*[10], DWI plays a key role in determining the nature of extraaxial cysts. None of the cases of demyelination seen in this study showed restricted diffusion. This is similar to the findings reported by Gass *et al*[4] which stated that increased diffusivity was more likely in demyelination due to vasogenic edema and myelin destruction with axonal preservation. Schwartz *et al*[11] 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.

LIMITATIONS

Some of the less common conditions like Creutzfeldt – Jacob disease were not seen in this study and only few cases of encephalitis and demyelization were observed. A larger study over a longer time period is recommended. Quantitative ADC values were not calculated in this study and a subjective assessment of the DW images and ADC maps were done.

CONCLUSION

Diffusion weighted magnetic resonance imaging is an important tool in evaluating intracranial lesions. While it assists in arriving at a specific diagnosis in some cases, in others it adds to the information obtained from conventional MRI sequences. Thus it is an essential addition to the list of sequences to be performed in any MRI study of the head. It is essential to compare the DWI images with ADC maps to ascertain the true nature of the signal intensity of the pathological condition.

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