Role of Diffusion Weighted Imaging in Intracranial Tumors with Pathological Correlation

J. S. Aswini Jyothi[1], P. Sree Hari[2], V. Karuna[3]

ABSTRACT

Introduction: Intracranial tumors can occur in all age groups and can be grossly divided into intra axial and extra axial tumors. In children, intracranial tumors are common in posterior fossa region. In adults these are more common in supra tentorial and intra axial regions. Aim and Objectives of the study were to test a hypothesis that ADC values can be used to differentiate tumor, edema and normal brain tissue, to compare and correlate ADC values of different components of tumor such as solid, necrotic, cystic component and perilesional oedema, normal brain parenchyma and to correlate the ADC values of tumor with the cellularity/histopathological grading of tumor/mass.

Materials and Methods: A prospective studyof DWI in Intracranial tumors and correlation with pathological findings, was conducted on patient population, referred for MR imaging of brain to Department of Radiology, Osmania General Hospital, Hyderabad during period between 2011 to 2013.

Results: Magnetic resonance imaging was performed in 63 patients with brain tumors in a 2 year period from December 2011 to September 2013. The patients had age group ranging from 2 months to 69 years with a mean age of 29 years. 29 were males, 23 were females. Most of the cases were in the first decade. The most common clinical presentation is intracranial hypertension (92.3%). Of 63 cases, most common tumor encountered in our study was Meningioma (11)

Conclusion: Diffusion weighted imaging is useful in differentiating epidermoid from arachnoid cysts. ADC values from the solid components can be used to differentiating CP- angle meninigiomas from schwannomas. However, the ADCvalues are not useful in differentiating "Tumour infiltrated edema" from Vasogenic Edema".

Keyword: Intracranial Tumors, DWI, ADC Values, Meningioma, Schwnnomas, Perilesional edema, Vasogenis edema.

INTRODUCTION

Intracranial tumors can occur in all age groups and can be grossly divided into intra axial and extra axial tumors. In children, intracranial tumors are common in posterior fossa region. MRI and Diffusion weighted imaging help us in classification and characterization of the lesions. With advent of DWI and its ADC values, the diagnosis, classification, characterization and location of the lesion is made more precise and accurate.

Physics of Diffusion Weighted Imaging

Diffusion-weighted (DW) magnetic resonance (MR) imaging provides image contrast that is dependent on the molecular motion of water, which may be substantially altered by disease. The phenomenon of diffusion was first described scientifically long before the systematic development of thermodynamics, by Robert Brown (1773-1858). In fact, this phenomenon was named "Brownian motion" after him.

Classical Brownian motion or diffusion means the random motion of water molecules. It can be isotropic or anisotropic. Following the first description of the NMR effect, independently by Bloch in Stanford and by Purcell at the MIT[1,2,3] in 1946, the sensitivity of the technique for molecular diffusion processes was marked in Hahn's publication on spin echoes only four years later.[4] The details were analyzed further by Carr and Purcell in 1954.[5]

Stejskal and Tanner provided an early description of a DW sequence in 1965.[6] They used a spin-echo T2-weighted pulse sequence with two extra gradient pulses that were equal in magnitude and opposite in direction. The final breakthrough for the technique came with the reports from Michael Moseley's group in San Francisco that diffusion-weighted imaging allows the detection of ischemic tissue within minutes after onset of stroke under experimental conditions.[14]

The signal intensity (SI) of a voxel of tissue is calculated as follows[15]:

SI = SI0 x exp (- *b* x D),

SI0 is the signal intensity on the T2-weighted (or *b*= 0 sec/mm2) image, the diffusion sensitivity factor *b* = γ2 *G*2 □2 (Δ - □/3), and ***D*** is the diffusion coefficient, g is the gyromagnetic ratio; *G* is the magnitude of, □ the width of, and D the time between the two balanced DW gradient pulses.

Apparent diffusion coefficient (ADC)[6]

According to Fick's law, true diffusion is the net movement of molecules due to a concentration gradient. However MR imaging, cannot differentiate molecular motion due to concentration gradients from molecular motion due to pressure gradients, thermal gradients, or ionic interactions. Also, with MR imaging we do not correct for the volume fraction available or the increases in distance traveled due to tortuous pathways. Therefore, when measuring molecular motion with DW imaging, only the apparent diffusion coefficient

[1]Assistant Professor, [2]Associate Professor, [3]Post graduate, Department of Radiology, Osmania General Hospital and Osmania Medical College, Hyderabad, Telangana, India

Corresponding author: Dr. J. S. Aswini Jyothi, Flat:204, Vasavi Bhuvana Apts, H: 8-3-981/ 1,3,4,6,8,10,11, Srinagar Colony, Hyderabad- 500037, Telangana, India

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(ADC) can be calculated. The signal intensity of a DW image is best expressed as: SI = SI0 x exp (- *b* x ADC)

MATERIALS AND METHODS

Patients for our prospective study were chosen from patient population referred for MR imaging of brain to Department of Radiology, Osmania General Hospital, Hyderabad during period from 2011 to 2013.

Image acquisition and Analysis

In all studies MR imaging was performed using a tailor made protocol with a clinical 1.5 T system (General electrical medical systems). A dedicated phased-array coil was used. Basic imaging protocol consists of fast spin echo T2 WI in axial, coronal and sagittal planes and DW, T1 and FLAIR images in axial plane. DW images were evaluated for the calculation of ADC values and ADC maps (General electrical medical systems). Absolute ADC value of Cystic, Solid and Necrotic component of tumor, Perilesional edema (T2 Hyperintensity) and normal appearing corresponding brain parenchyma, are calculated.

ADC values were normalized by dividing ADC values of tumors by those of normal appearing regions and the quotient will be expressed as a ratio.

Operated case will be evaluated by experienced histopathologist for the grading and cellularity of tumor.

All the collected data was analysed by using proper Bio-statistical methods.

Parameters for diffusion weighted sequence

Slices with 30% distance factor, Slice thickness 5 mm, TR-1000ms, TE-81ms, FOV Read-26 cm, FOV Phase, Scan time- 0.16 sec, Voxel size-1.8 x 1.8 x 5.0 mm, B-value- 0 and 1000, Echo spacing –0.73,

Bandwidth-12.

Post contrast T1W Images were employed in some patients

Contrast used: Gadolinium contrast (Omniscan, GE health care, 0.1 mmol/kg body weight) used. No contrast reactions were encountered.

Scan time varied from 15 mins to 21 mins for sequences other than DWI. Images were analyzed on Functool 2 software version

Mean ADC value for each tumor was calculated using two to five regions of interests. In cases with contrast studies the ROIs were put in areas that were enhancing (for tumors having enhancing parts). For unenhancing tumors, ROIs were put in solid parts determined with the help of information gathered from other sequences.

Two experienced neuropathologists did histopathological examination. Few tumors were surgically resected. Rest of the patients had undergone stereotactic biopsy.

RESULTS

Magnetic resonance imaging was performed in 63 patients with brain tumors in a 2 year period from December 2011 to

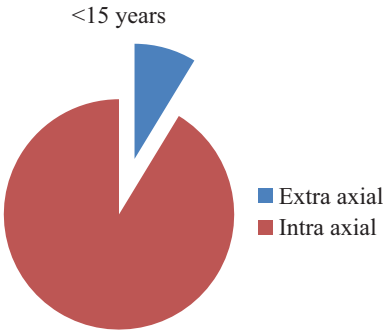

Figure-1: Location of tumours <15yrs

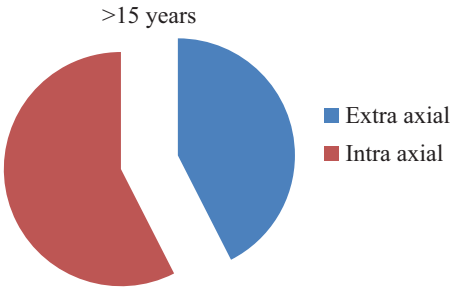

Figure-2: Location of tumours in >15yr

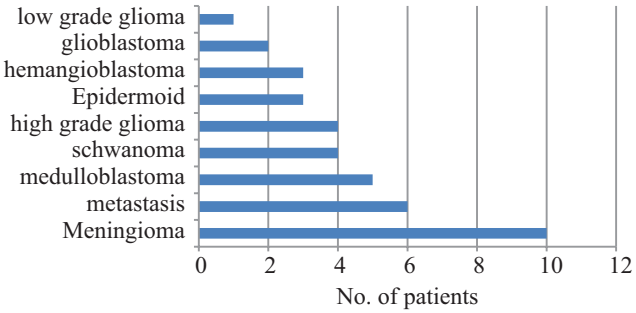

Figure-3: Characterisation of lesion in >15years group

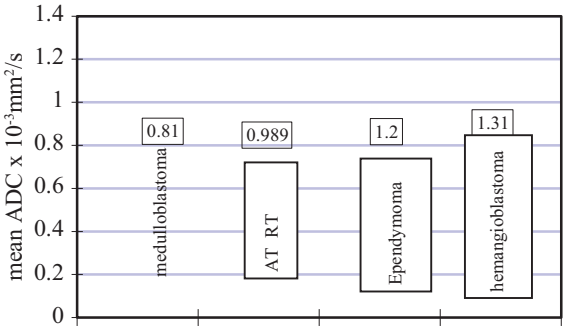

Figure-4: ADC Values of paediatric posterior fossa tumours

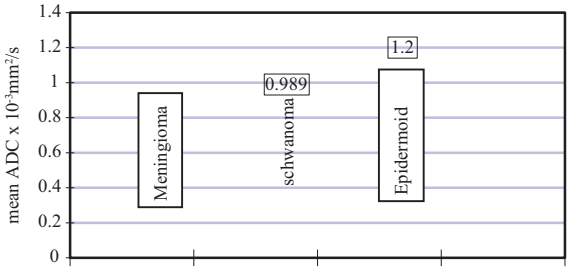

Figure-5: Mean ADC in Extra axial lesions

September 2013. The patients had age group ranging from 2 months to 69 years with a mean age of 29 years, 29 were males and 23 were females. Most of the cases were in the first decade. The most common clinical presentation is intracranial hypertension (92.3%). Of 63 cases most common tumor encountered in our study was Meningioma (11) followed by Medulloblastoma (9), Metastasis (6), High grade glioma (7), Brainstem glioma (6), Pilocytic astrocytoma (5), Vestibular schwannoma (5), Ependymoma (4), Hemangioblastoma (3), Epidermoid tumor (3), Glioblastoma (2), AT-RT (1).

In <15years age group, Intra axial tumors (21) were more common than Extra axial tumors (2). Most common tumor encountered was Pilocytic astrocytoma (6) followed by Medulloblastoma (5), Diffuse low grade glioma (4), High grade glioma (3), Ependymoma (2), AT-RT (1), B/L Vestibular schwannoma (1), Meningioma (1). In >15 years group Most common tumor encountered was Meningioma (10) followed by Metastasis (6), Vestibular schwannoma (4), Medulloblastoma (5), High grade glioma (4) Hemangioblastoma (3), Epidermoid tumor (3), glioblastoma (2), Ependymoma (2), low grade glioma (1)

DWI characteristics of different tumors: Tumors with restricted diffusion are Medulloblastoma, Epidermoid tumor, AT-RT. Rest of the tumors were not restricted on diffusion. All Acoustic schwannomas were isointense to cortex on DWI and all Meningiomas were hyperintense to cortex.

Of the all posterior fossa tumours Medulloblastomas showing lowest ADC values ranging from 0.67 to 0.99, (mean 0.83), Atypical teratoid rhabdoid tumour ranging from Ependymoma ranging from 1.0 to 1.21 (mean 1.1), Pilocytic astrocytoma ranging from 1.3 -1.92 (mean 1.61).

DISCUSSION

Role of diffusion weighted imaging in brain tumors was practically restricted to differentiation of epidermoid and arachnoid cyst. Diffusion imaging plays a small role in the detection of brain tumors. Compared with the sensitivity of conventional MR imaging, particularly T2 weighted, FLAIR and contrast enhanced T1 weighted sequences for the detection of brain tumors; the sensitivity of DW MR images and ADC maps is low.

One reason for this low sensitivity is that voxel sizes in diffusion MR imaging are generally larger than those used in conventional pulse sequences because of signal to noise limitations in the underlying echo-planar diffusion sequence. In addition there is no evidence that the contrast between most brain tumors and normal brain parenchyma on DW MR Images and ADC maps is superior to that found on images obtained with T2 W or FLAIR MR imaging techniques. Although reports of apparent decrease in diffusivity of few cerebral tumors have been published, there are very few studies which have evaluated diffusivity quantitatively. Our aim was to study the diffusivity of all the brain tumors quantitatively and correlate it with histopathological information such as subtype as well as grade of malignancy.

In our study, 11 cases of Meningiomas are included. Of these, 9 cases were showing no restriction on diffusion but

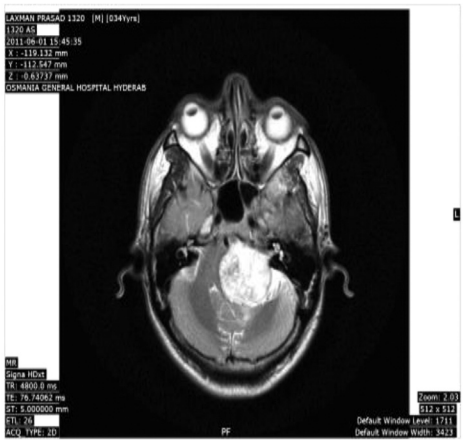

Figure-6: T2W MR show hyperintense lesion - s/o Schwannoma

isointense to cortex. 2 cases showed areas restriction within the lesion with less mean ADC values. Meningiomas showing ADC Values Ranging from 0.7 -1.2X 10-3.

Correlation between ADC values and tumor cellularity in both gliomas and meningiomas as study conducted by Kono et al -2001.[13] In our study, on comparision of vestibular schwannomas and meningiomas, signal intensity on T2W is higher in vestibular schwannomas than in meningiomas. Signal heterogenicity is common in vestibular schwannomas than in meningiomas. On DWI vestibular schwannomas were iso to hypointense to cortex with ADC values ranging from 1.2 -1.9 (mean 1.55) where as meningiomas were hyperintense to cortex with ADC values ranging from 0.7 -1.2 (0.95).

In our study, on comparision of posterior fossa tumours, all medulloblastomas are showing restriction with ADC values ranging from 0.67 -0.99 (mean 0.83). Most of the cases of ependymomas (except 1 case) show no restriction on DWI with ADC values ranging from 1 -1.21 (mean 1.1). This one case was diagnosed based on the associated finding (location, T1 Hyperintensity, Blooming on GRE). This is due to intratumoral hemorrhage which is restricted on DW image in Hyperacute, acute, early sub acute stage. This is same as said by Scott W. Atlas et al.[7] who indicate that hematomas composed of any and all of the evolutionary stages theorized to contain hemoglobin within intact RBCs (ie, hyperacute, acute, and early subacute hematomas) show significantly reduced ADC values compared with the single hematoma state theorized to be comprised of lysed RBCs (ie, ‘‘free’’ methemoglobin in subacute-to-chronic hematomas).

In our study, there were 5 cases of posterior fossa pilocytic astroctomas of which 2 cases show typical imaging appearance of cystic lesion with mural nodule, 2 cases are solid lesions arising from vermis of the cerebellum. These cases were diagnosed based on appearance on T1, T2 W images (less heterogenous) and DW images. All the case of pilocytic astrocytomas were not showing restriction with ADC values ranging from 1.3 -1.92 (with mean 1.61). ADC values of pilocytic astrocytoma, ependymoma, medulloblastomas are 1.3 -1.92, 1 -1.21, 0.67 -0.99 respectively. These are comparable to study by Z. Rumboldt et al.[8]

Brainstem gliomas were seen in 5 cases in our study. All cases

showed enlarged pons and basilar artery encasement. 4 cases showed enhancing component, 1 case was non enhancing. All were showing mixed hypointense on T1W, hyperintense on T2W, heterogeneous on FLAIR and not restricted DWI. With ADC values ranging from 1.1 -1.8 (mean 1.5). These findings are comparable to those in Neuroradiology 2011.[9]
We encountered 7 cases of high grade gliomas. Of these, the cases presented at the age of 2 years were more heterogenous on T1WI, T2WIwith minimal peri lesional edema. Based on these findings these were diagnosed as PNET. All the cases were showing diffusion restriction with ADC values ranging from 1 – 1.3. We encountered two cases 0f glioblastomas in the age distribution of 50 to 60 years. IN these, one lesion located in corpus callosum was showing ADC values of 1.2 -1.4, based on the location it was diagnosed as Glioblastoma even though not showing significant restriction. In Another case, lesion located in left cerebellar hemisphere, not showing restriction with ADC values ranging from 1.2 -1.8, based on the location and age it was diagnosed as Metastasis. These findings were contradictory to findings shown in Neuroradiology 2011.[9]
Epidermoid tumors were seen in 3 cases, two were males and one in female. Both cases showed CSF SI on T1WI, T2WI sequences, not fully suppressed on FLAIR and with extension along cisternal spaces, encasement/ engulfment of vessels and nerves, no contrast enhancement and restricted on DWI. These findings go with findings shown in American Journal of Neuroradiology.[10] Both cases were correlated with histopathology.
Hemangioblastomas were seen in 3 cases, all were males with mean age was 39 years. 2 cases seen in cerebellar hemisphere were showing a large cyst and with isointense mural nodule which is intensely enhancing. One case was seen in vermis, which is predominantly solid with few cystic areas with heterogeneous signal intensity on all sequences and on contrast administration is heterogeneous and showing intense contrast enhancement. Multiple flow voids were seen in all cases. All features were histologically correlated. DW images in 2 of 3 patients with cerebellar hemangioblastomas showed notable hypointensity in locations corresponding to areas of solid enhancement on contrast enhanced MR images. This finding was not seen in other cellular tumors including medulloblastomas, metastases and lymphoma. In the present study, mean ADC value of cerebellar hemangioblastomas was higher than other posterior fossa tumors. However the difference was not significant.
Metastases were seen in 7 cases with mean age being 49 years. The primary was found to be lung carcinoma in 3 cases, breast carcinoma in 1 case, ovarian carcinoma in 1 case, thyroid carcinoma in 1 case and unknown primary in 1 case. 2 cases had associated supratentorial metastases, 1 case had bilateral cerebellar metastases. The opinion of many authors is that metastatic lesions are the commonest lesions in elderly involving the posterior fossa. Lung and Breast are the common primary sites, are concurrent with our observation. All cases showed heterogeneous enhancement and not restricted on DWI with ADC values ranging from1 – 1.2. These findings are correlated with the study conducted by Eur J Radiol 2010 Apr.[11]
Detection of restricted diffusion on DWI in intra cerebral metastases is not rare, particularly if the primary tumor is lung or breast cancer. However we found that there is no correlation between the metastasis showing restricted diffusion and primary pathology.
ADC values of peritumoral edema was calculated in all cases of high grade gliomas which was showing ADC values ranging from 1- 1.15. There is no difference in ADC values between tumour infiltrated edema and vasogenic edema. These findings were consistent with study conducted by Van Westen D et al 2006[12] who tried to determine whether the apparent diffusion coefficient (ADC) and fractional anisotropy (FA) can distinguish tumor-infiltrated edema in gliomas from pure edema in meningiomas and metastases. In his study, thirty patients were studied: 18 were WHO grade III or IV gliomas, 7 meningiomas, and 5 metastatic lesions. They concluded that values and lesion-to-brain ratios of ADC and FA in areas with T2-signal changes surrounding intracranial tumors and adjacent normal appearing white matter were not helpful for distinguishing pure edema from tumor-infiltrated edema when data from gliomas, meningiomas and metastases were compared.

CONCLUSIONS

Diffusion weighted imaging is useful in differentiating epidermoid from arachnoid cysts. ADC values from the solid components can be used to differentiating CP- angle meningiomas from schwannomas. The ADCvalues correlated with tumor cellularity for both astrocytic tumors and meningiomas. The ADCvalues not useful in differentiating tumour infiltrated edema from vasogenic edema. The ADC values useful in differentiating the paediatric posterior fossa tumours.

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